Modes of GIS Provision and their Appropriateness for Neighborhood Organizations: Examples from Minneapolis and St. Paul, Minnesota

Helga Leitner, Sarah Elwood, Eric Sheppard, Susanna McMaster, Robert McMaster

Abstract: *In the last decade, community organizations have become significant users of geographic information systems (GISs). They gain access to GIS through various institutional arrangements, but there has been no systematic comparison of the appropriateness of these different modes of GIS provision for community organizations. Drawing on research with Minneapolis and St. Paul neighborhood organizations, we present descriptions of five modes of provision, and propose that they differ along three important dimensions: stakeholder-community organization relations, communication structures, and geographic location. We utilize these dimensions to assess the five modes with respect to their potential costs and responsiveness to community organizations' needs, and suggest how this framework can be used to seek and assess alternative modes of provision to those used in Minneapolis and St. Paul, Minnesota.*

Introduction

During the past decade, the increasing use of geographic information systems (GISs) for a wide array of planning and problem-solving activities by federal, state, and local authorities has gradually been extended to include community organizations. In part, such organizations have initiated this development themselves, but external institutions also have played an important role. Federal, state, local, and non-governmental agencies have sponsored numerous initiatives intended to help community organizations overcome the barriers they face in gaining access to GIS and other information technologies and to spatial data. The Department of Housing and Urban Development (HUD), for example, developed and distributed its Consolidated Planning software with the intention of enabling community organizations to gain access to GIS, census data, and information on HUD housing and community development projects (U.S. Housing and Urban Development 1995). In 1998, Vice President Al Gore announced a federally-sponsored program providing grants to help communities gain access to the National Spatial Data Infrastructure clearinghouse (State Cartographer's Office 1998). State, local, and non-governmental agencies have also initiated many efforts to assist community organizations in gaining access to information technologies and associated data. In Milwaukee, for example, non-profit groups have collaborated to create the Milwaukee Data Center, providing GIS and data to community organizations (Barndt and Craig 1994).

Since most GIS software was not designed with community organizations in mind, there are important questions about whether GIS is appropriate in this context. Existing research has documented particular constraints that community organizations face when they seek to use GIS. Such organizations frequently have difficulty obtaining funds to purchase and maintain hardware and software, lack the local expertise (technical and analytical skills) and personnel to use GIS effectively, and have difficulty gaining access to digital spatial data. Data access often depends entirely on the willingness of government agencies to share data and on freedom-of-information regulations (Barndt and Craig 1994, Barndt 1998, Elwood and Leitner 1998).

The growing utilization of GIS by neighborhood organizations also raises important questions about access to GIS and its potential benefits for these groups. Many individuals and agencies advocating greater access to GIS simply assume that the technology is beneficial for neighborhood organizations, as have a number of academic researchers writing about the empowerment potential of GIS (Heikkela 1998, Klosterman 1998). This sentiment is reflected in one of the major themes of the 1999 annual meeting of the Federal Geographic Data Committee: "Using GIS to Build Better Communities." Other proponents directly link use of these technologies with greater participation and the power of citizens and citizen groups in decision-making processes affecting their communities. Vice President Gore argued that GIS would:

> …help communities help themselves by putting more control, more information, more decision-making power into the hands of families, communities, and regions to give them all the freedom and flexibility they need to reclaim their own unique place in the world. (State Cartographer's Office 1998: 1)

In contrast, some researchers are skeptical that GIS access empowers citizen and community groups in planning and decision making (Aitken and Michel 1995, Pickles 1995, Sheppard 1995, Elwood and Leitner 1998, Harris and Weiner 1998, Obermeyer 1998). Such disputes parallel more general debates in the planning literature about the extent to which public par-

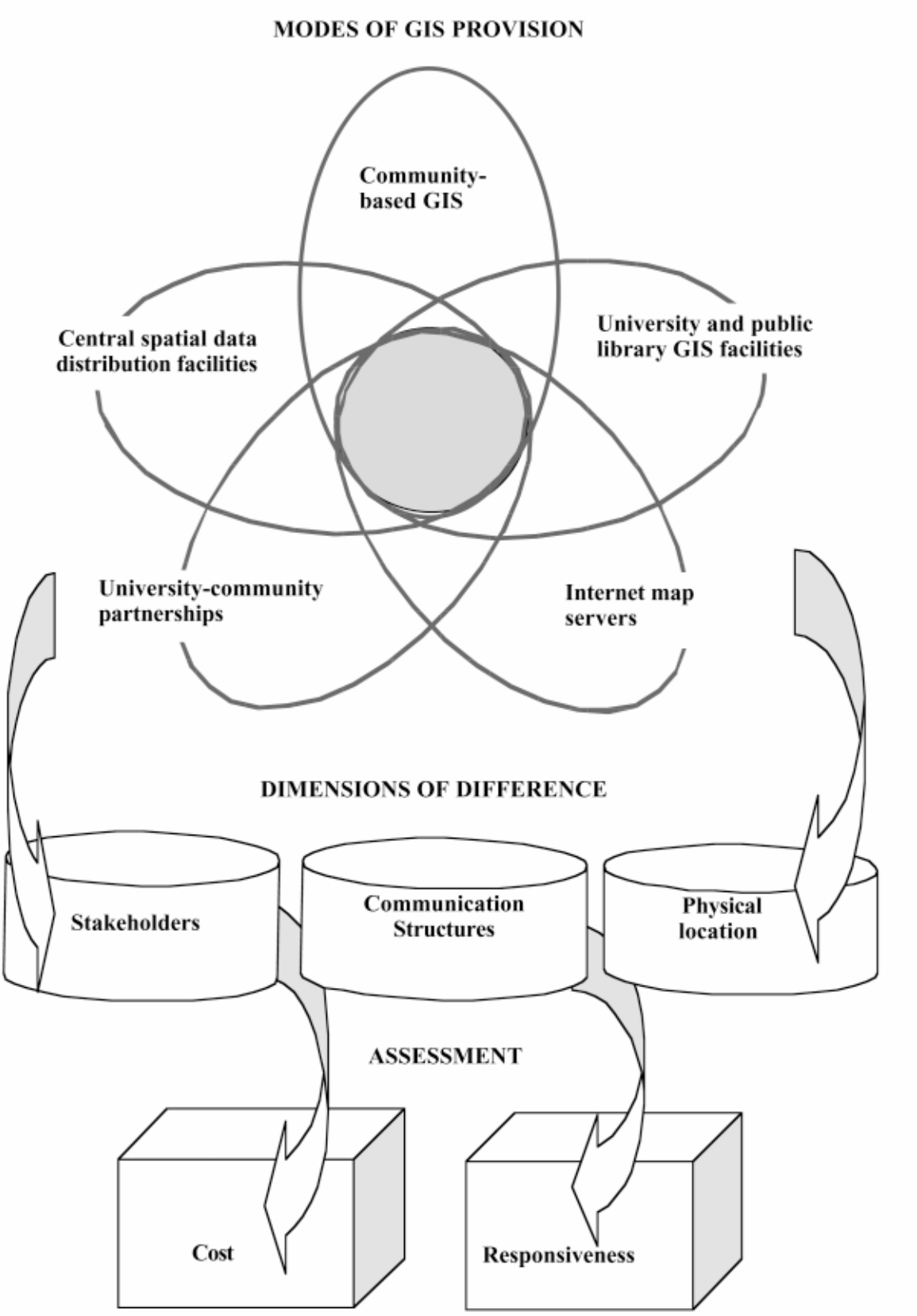

Figure 1: Community organizations using GIS: modes of GIS provision, dimensions of difference, and assessment.

Central spatial data distribution facilities (e.g., City of Minneapolis' GIS Map Room)
GIS facilities in universities and public libraries (e.g., Automated Cartographic Information Center at the University of Minnesota)
Community-based (in-house) GIS (e.g., Minneapolis' Powderhorn Park Neighborhood Association)
University-community partnerships (e.g., Urban GIS course, Macalester College Action Research, University Neighborhood Network)
Internet map servers (e.g., Phillips Neighborhood Environmental Inventory Project)

Table 1: Different Modes of GIS Provision for Community Organizations in the Twin Cities

ticipation enhances the power of citizens to influence decisions affecting their communities (Gans 1991, Grant 1994, Tauxe 1995, Baum 1997 and 1999, Healey 1997, Sandercock 1998). The empowerment potential of GIS is as yet poorly understood, due to a dearth of empirical studies (however, see Sieber 1997, Ramasubramanian 1998, Elwood 2000). The spread of GIS to neighborhood organizations is not awaiting resolution of these debates, but is proceeding apace. More community organizations are using GIS and spatial data in their day-to-day activities, gaining access via a wide variety of institutional arrangements and relationships. In this spirit, we set aside questions of empowerment of citizens and communities in planning and decision-making processes to examine different modes of provision through which community organizations are gaining access to GIS.

There has already been extensive study of the diffusion and implementation of GIS in organizations (Onsrud and Pinto 1991 and 1993, Obermeyer and Pinto 1994, Campbell and Masser 1995, Pinto and Onsrud 1997). These studies identify a range of organizational and managerial characteristics and practices that foster the implementation and use of GIS, but community organizations have unique characteristics and needs. Will Craig and Michael Barndt identified many of these characteristics and the problems they create for GIS use by community organizations (Barndt and Craig 1994, Craig 1994, Sawicki and Craig 1996, Barndt 1998). In this article, we build on these insights, seeking to develop a systematic comparison of the characteristics, advantages, and disadvantages of a number of the modes of provision that community organizations currently utilize in order to gain access to GIS.

We begin by describing five different modes of provision available to community organizations in Minneapolis and St. Paul, Minnesota. Second, we conceptualize three dimensions of difference (stakeholder-community relationships, communication structure, and location) along which these various modes of provision can be distinguished, suggesting that these dimensions of difference in GIS provision have particular advantages and disadvantages for community organizations. Third, we discuss the putative advantages and disadvantages of different modes of provision with respect to community organizations' particular needs and constraints, and the social, economic, and human costs involved in accessing and using GIS. We also propose that this conceptual framework may be used to aid in normative reasoning and in identifying modes of provision that are responsive to the specific needs and constraints of community organizations. Figure 1 visualizes the conceptual structure of the paper, linking the modes of provision, the dimensions of difference, and assessment.

The arguments presented are intended as exploratory rather than definitive. Tentative hypotheses are suggested regarding modes of provision, developed inductively from our own experiences between 1996 and 1999 in a variety of participatory research endeavors with 10 neighborhood organizations in Minneapolis and St. Paul, Minnesota. These experiences, described below, have enabled the authors to observe different arrangements for facilitating access to and use of GIS and GIS-based information by neighborhood organizations. It is hoped that others will debate, refine, and improve on the ideas based on their own experiences with these and other modes of provision, as well as by undertaking systematic comparative case study research.

In our experience, there is no single inherently superior mode of providing GIS to community organizations. Community organizations are not locked into one mode of provision, but use a variety of strategies to assemble the expertise necessary for GIS acquisition and use, and shift this mix as circumstances change. Further, the efficacy of different modes of GIS provision varies depending on the larger spatial and temporal context within which the organization is embedded. This article, however, attempts to describe and conceptualize the modes of provision available to community organizations, rather than examining how context shapes which modes are adopted.

Different Modes of Provision

Five modes of provision encountered in our research and teaching activities in the Twin Cities are described in this section (Table 1). In the Minneapolis Community GIS Project, a collaborative research project with four Minneapolis neighborhood organizations, we sought to assess the participating organizations' access to, needs for, concerns about, and perceptions of the utility of GIS, and attempted to facilitate access to GIS and spatial data (Elwood and Leitner 1998). In the Phillips Neighborhood Environmental Inventory Project, we developed a GIS-based neighborhood environmental inventory in collaboration with a neighborhood-based nonprofit organization and local residents; this inventory is available as an Internet map server. One author has investigated the social and political impacts of GIS use in community-based planning by a Minneapolis neighborhood organization (Elwood 2000). Finally, we worked with community organizations through community service learning and action research projects in applied GIS courses. Together, these activities have given us experience with central spatial data distribution facilities, GIS facilities in universities and public libraries,

community-based GIS, University/Community partnerships, and Internet map servers.

Central Spatial Data Distribution Facilities

In this mode of provision, a government agency maintains an office responsible for disseminating spatial data and maps to clients (in digital or hard-copy format), some of who may be community organizations. Organization staff or volunteers usually must travel to the office to request and obtain materials. Their interaction with GIS is indirect. They must communicate their needs to office staff, who then manipulate the data or create maps. Such facilities vary in the extent to which data and maps can be customized for clients, in whether clients can bring their own data for analysis and mapping, and in the degree of advice and assistance that staff are prepared to offer clients.

The City of Minneapolis' GIS Print Room is an example of such a facility. The Print Room was established through the Department of Public Works to provide, on request, maps and data drawn from the City of Minneapolis' GIS database to city departments, government agencies, and the general public. Parcel-level data are available on housing value, condition, and tax assessments. Products can be obtained in digital and hard-copy form at a current cost of between $10 and $25 for 2' x 3' color maps and $450 per megabyte for digital files. Given the cost of digital files, most community organization clients purchase hard-copy maps unless they are able to get their city council representative to intercede on their behalf. Clients can provide their own data for address matching (e.g., a list of vacant houses in a common spreadsheet form), and have the Print Room create a map using these data.

GIS Facilities in Universities and Public Libraries

Another way in which community organizations gain access to GIS and spatial data is through publicly accessible GIS facilities in public or university libraries. In these facilities, community organization staff or volunteers visiting the facility can use base maps and spatial data maintained on GIS software. At most facilities, users must select from predefined data sets or maps, generally primarily based on United States census boundary (TIGER) files and data. However, some facilities provide users access to a wider range of data and enable them to map and analyze their own data. The level of assistance or advice that facility staff can offer clients will vary. Assistance in operating hardware and software is usually available, but the staff is not necessarily prepared to give clients advice about which maps, data sets, or methods of analysis are appropriate for particular issues or problems. While the principal actors in this arrangement are the community organization and the library staff, other stakeholders, such as agencies providing hardware, software, or data to the library, also shape the possibilities of this mode for community organizations.

The University of Minnesota's Automated Cartographic Information Center (ACIC) is an example of such a facility. It is located in the University's map library and is open to the general public, although new users must attend a brief training session. Use of the ACIC is free, although there is usually a charge to print maps (in 2000, this ranges from $0.10 to $1.00) . A wide range of publicly accessible data and base maps is available, and users can also incorporate and analyze their own data. Local and state government employees, community organizations, and other local non-profit organizations also use the ACIC. The ACIC is typically staffed by one person, who may or may not have expertise beyond hardware and software operation. Thus, clients cannot expect to get detailed advice or assistance with analysis.

Community-Based (In-House) GIS

The establishment of GIS and databases in a community organization's office is still a rare and rather recent phenomenon in the Twin Cities, existing in only a handful of neighborhood organizations. Some organizations (such as Minneapolis' Powderhorn Park Neighborhood Association) have accomplished this fairly independently, while in other cases the creation of an in-house GIS has been facilitated with the help of outside partners, such as University faculty. For instance, in the Minneapolis Community GIS Project, we attempted to help four neighborhood organizations establish in-house GIS and databases.

One example of an in-house GIS is the Powderhorn Neighborhood in Minneapolis. In a recent comprehensive planning process, the Powderhorn Park Neighborhood Association (PPNA) utilized money from the Minneapolis Neighborhood Revitalization Program to acquire hardware and GIS software, and to establish a comprehensive database on neighborhood properties. The database contains information on property zoning and tax status; housing tenure, conditions, and ownership; and a record of nuisance activities or building-code violations. Users can perform simple querying and mapping of the data. The database is used for monitoring neighborhood conditions, planning PPNA activities and programs, evaluating the success of problem-solving efforts, and coordinating action among multiple actors at work in the neighborhood. For instance, PPNA used the database to analyze housing conditions in the neighborhood in 1998 and developed a repair grant program targeted toward an area of the neighborhood identified as most in need of certain repairs. After completion of the program, PPNA used its GIS and database to evaluate changes in housing conditions and to assess whether the repair grant program had been successful, should be continued, or could be focused on another location.

An in-house GIS makes it easier for community residents as well as staff to be involved in using it. The GIS may contain data collected by the community organization as well as data obtained from government sources. Choices made by organization staff and residents about hardware, software, and design of databases affect their ability to actively manipulate data and tailor it to their own needs. While the community organization has primary responsibility for and control over an in-house GIS, other stakeholders provide assistance to the organization in developing the GIS and can shape its suitability. A community organization may obtain hardware, software, data, and training independently, using general operating funds and seeking little assistance or ad-

North End Area Revitalization Goal: To portray in map form demographic and housing data in order to inform community presentations and enhance understanding of basic trends.
Neighborhood Development Center (NDC) Goal: To examine ethnic diversity and economic conditions in areas served by small businesses supported through NDC.
Summit University Planning Council (SUPC) Goal: To create a series of maps using data collected by SUPC to be used in community planning.
Dayton's Bluff Neighborhood Housing Services, Inc. (DBNHS) Goal: To create maps of neighborhood demographics, and of DBNHS investments in the neighborhood, for use in planning DBNHS' loan and grant programs to homeowners, home buyers, and commercial property owners in the area.
Hamline-Midway Coalition Goal: To create maps of demographic information to accompany the Hamline-Midway Community Action Plan.
Homelink Mortgage Program Goal: To create maps of successful mortgages as related to other demographic variables in order to inform their efforts to match potential buyers with appropriate mortgage lending and education programs.
Frogtown Community Development Corporation Goal: To map location of contract-for-deed properties in order to examine patterns of contract-for-deed sales in the Frogtown neighborhood.

Table 2: University-Community Partnerships –Examples of GIS Applications

vice, but often other public or private organizations provide these or supply grants to purchase the GIS with conditions of use attached.

University-Community Partnerships

Through a variety of mechanisms, universities are increasingly involved in assisting community organizations with their information and mapping needs. Some models of university-community partnerships involve coursework, such as community service-learning requirements in urban GIS courses, while others are formed through action research (participatory research) projects involving cooperation among faculty, students, and community members.

In community service learning, students provide a service to the community, such as developing a GIS application in collaboration with a community organization, and then reflect on the lessons learned from the experience. The level of interaction between community organizations and the students carrying out the analysis varies. Sometimes organization staff or volunteers meet directly with students to identify specific goals, sources of data, and specific mapping needs, but in other instances, they delegate this to the students and faculty. In the Twin Cities, community organizations have been able to establish such coursework-related partnerships through the University Neighborhood Network (UNN), funded by The Minneapolis Foundation and operated by the University of Minnesota's Center for Urban and Regional Affairs. The UNN identifies courses at Twin Cities colleges and universities that address issues relevant to urban neighborhoods and that also have a student research component. Neighborhood organizations in Minneapolis and St. Paul develop project descriptions for student research, cooperating faculty members build the neighborhood research project into their course requirements, and students and the involved organizations together establish the specific tasks to be carried out. Table 2 summarizes recent research projects carried out through the UNN, completed by students in a University of Minnesota urban GIS class in the spring of 1998.

Participatory research projects with university faculty and students are a second means for community organizations to gain university assistance, either in obtaining GIS hardware, software, and training or with data acquisition and mapping. The level and duration of interaction and communication between community organizations and university researchers vary, depending on the specific goals of the research, the degree of involvement of community members in the research process, and the location where research and analysis are carried out. Some projects have a commitment to fostering community expertise with respect to GIS operation and analysis, whereas others are more limited in scope, simply providing maps and analysis to the community. An example of the former type of partnership is the collaboration between the University of Minnesota's Department of Geography and the Green Institute in Phillips Neighborhood, in developing the Phillips Neighborhood Environmental Inventory. The partnership identified appropriate data to include in this inventory, incorporating both university and neighborhood perspectives. University students and faculty then collected data, developed databases, and mapped the results using MapInfo, creating a cartographic inventory to support neighborhood sustainability. The Green Institute was provided with MapInfo software and training, but the final inventory has been made available on a web site (see below) because the Green Institute showed little interest in maintaining a GIS in its offices.

Another example is a project in which one of the authors has participated, involving faculty and students from different departments at Macalester College in St. Paul, local government agencies, and community organizations from east St. Paul. Designed as action research, this project has involved community members in defining, examining, and identifying solutions to problems in the neighborhood. Faculty and students from Macalester College's Department of Geography contributed to this project by developing GIS-based community profiles and

maps addressing community concerns about housing, crime, and education.

Internet Map Servers

Community organizations can also be provided with maps and data from Internet map servers, some of which are GIS-based. This mode of provision requires that some individuals or institutions, such as local government agencies, universities, or non-governmental organizations, establish a web site providing spatial data and maps. Currently, most sites are oriented toward simple cartographic display, but some allow users to query or analyze spatial data. In the Twin Cities, a number of web sites provide spatial information relevant to communities, including Minnesota Pollution Control Agency maps of airborne toxic chemicals (http://www.pca.state.mn.us/air/at-cep.html); Metropolitan Airports Commission maps of flight tracks and daily noise levels in neighborhoods (http//www.macavsat.org); and some neighborhood-specific spatial data, such as maps of community gardens and boarded and vacant properties created and maintained by Phillips Neighborhood residents on the neighborhood web site (http//www.pnn.org).

With availability of maps and spatial data on the Internet, community organizations can gain access to maps and data from networked computers in their offices, the homes of community residents, or public facilities with Internet access. Clearly, the use of such information is limited to individuals and institutions with access to the Internet. As well, individuals and community organizations do not directly control the data on such sites, but can access only the data or maps made available by the web-site designer. Finally, these sites may not provide on-line help, possibilities for spatial queries, or answers to frequently asked questions.

As part of the Phillips Neighborhood Environmental Inventory Project, the authors established an Internet map server providing geographic data and maps describing the social and physical environment in the Phillips Neighborhood (http://www.geog2.umn.edu/mapserv/pneiweb/Pneinet/PNEI.html). This map server is located at the University of Minnesota and will be linked to the Phillips Neighborhood web site. The server includes a summary of how the inventory was created; a series of maps at block-group resolution highlighting the socioeconomic structure of the neighborhood, the parks and community gardens, public transit and bicycle routes, the location of facilities storing or emitting toxic chemicals, and the location of schools, senior citizens' residences, and child-care centers; and suggestions for how to read the maps. Users may modify some of the maps by selecting which variables to display.

Differentiating Modes of Provision: Stakeholders, Communication Structures, Location

The five modes of provision described here display many specific differences and similarities, as evident in the descriptions and definitions provided. In this section, we argue that three overarching dimensions of difference can be abstracted from these specificities. These dimensions are: 1) the stakeholders involved in the provision of GIS technology and data; 2) the communication structure within which community organizations utilize a GIS; and 3) the physical location of the GIS relative to the community organization itself. While all abstractions run the danger of oversimplification, we argue that in this case such abstractions are useful in three respects. First, they provide a basis for under-

DIMENSIONS	CATEGORIES
Stakeholders (including providers)	*Types of stakeholders:* Local and non-local state agencies Non-governmental organizations (NGOs) Educational institutions Private industry *Types of relationships between stakeholders and community organizations* Cooperation Compliance Collaboration Control
Communication Structures	*Human-computer interaction* No direct use Passive use Active use Pro-active use *Individual vs. collective decision-making* *Intra- vs. inter-organizational communication*
Geographical Location	*In-house vs. remotely located GIS*

Table 3: Dimensions of Difference in Modes of GIS Provision

Example	Stakeholding		Communication Structures	Geographic Location
	Principal Stakeholders	Relationships		
Central spatial data distribution facilities: City of Minneapolis Map Room	Minneapolis Public Works Department Community organization	Control	No direct use Individualistic Intra-organizational	Remote
GIS facilities in universities and public libraries: ACIC at the U of MN	University provider Facility staff Community organization	Control	Passive and/or active use Individualistic Intra-organizational	Remote
Community-based GIS: Powderhorn Park	Data, hardware, and software providers Funders Community organization	Compliance	Active use Individualistic Potentially intra-organizational	In-house
University-community partnerships: U of MN/Phillips Neighborhood Collaboration	University researchers Community organization	Collaboration	No direct use and/or passive use Individualistic Intra-organizational	Remote
Internet map servers: Phillips Neighborhood Environmental Inventory	Data/site provider Community organization	Control	Passive use Individualistic Intra-organizational	In-house

Table 4: Differentiating Modes of GIS Provision for Community Organizations in the Twin Cities

standing the advantages and disadvantages of different modes of provision for community organizations, a point developed in the next section. Second, such abstractions may be useful in helping imagine alternative modes of provision, which may meet the distinctive needs of community organizations better than the five discussed here. Third, they may help us understand the strategic choices that community organizations make when more than one mode of provision is available.

In the remainder of this section, each of these dimensions is discussed in terms of alternative forms that they may take (Table 3). In order to provide a sense of how the three dimensions apply to particular cases, Table 4 takes one example of each of the modes of provision discussed above and categorizes it according to the elements of Table 3. Again, note that the categories within each dimension are neither mutually exclusive nor fixed, and by no means are exhaustive. Many community organizations creatively employ multiple strategies, developing GIS practices that mix different categories and changing this mix as necessary. Nonetheless, these dimensions of difference are presented as a possible starting point for making sense of the complex practices that community organizations develop.

Provision of GIS to community organizations typically involves many more stakeholders than the community organization itself. The term stakeholder is used here to refer to providers of GIS technology, training, and/or spatial data, as well as other individuals and institutions with an interest in what happens in the neighborhood. Stakeholders may be local, state, and federal actors and agencies, non-governmental organizations and other nonprofit agencies, private industry (particularly firms marketing GIS software and data), and educational institutions, each with their own institutional priorities and interests.

Providers may influence modes of provision through specific contractual arrangements, through control over the kinds of hardware and software used or the manner in which they can be used, and through control over the data made available and how the data can be mapped. For example, HUD initially provided a

	Equal Power	Unequal Power
Independent Actors	COOPERATION	COMPLIANCE
Interdependent Actors	COLLABORATION	CONTROL

Table 5: Four Types of Relationships between Community Organizations and External Stakeholders

"stripped down" version of commercial GIS software to neighborhood organizations at a low price, but the software was limited with respect to the analyses that could be performed.

The role of stakeholders will depend not only on who the stakeholders are, but also on their degree of involvement and their relationship with the community organization. Van Tulder and Ruigrok (1997) argue that the relationships between potential partners depend on both their relative power and the degree of dependence among them. Simplifying their scheme, four types of relationships between community organizations and other external stakeholders can be identified (Table 5). When all players are independent, hold equal power, and have convergent agendas, they may engage in cooperation. When players are independent, but community organizations have less power than external stakeholders do, community organizations will find themselves in a relation of compliance. When community organizations and external stakeholders are co-dependent (i.e., they depend equally on one another), the relationship can be described as collaboration. Finally, if community organizations are dependent on external stakeholders, giving them less power to influence the relationship, then stakeholders exert control over community organizations. Powerful stakeholders potentially can shape the degree to which a mode of provision is responsive to community organizations' needs, implying that modes of provision characterized by cooperation and collaboration are more likely to be responsive.

The communication structure within which a GIS is utilized describes the manner in which users interact with the technology and with each other. Three overlapping but distinct aspects of communication structures are worthy of attention: the degree to which human-computer interaction is active and thus supports a user-driven agenda, the degree to which a GIS can be employed as a part of the collective brainstorming and decision-making activities that typically characterize community organizations, and the degree to which communication between community organizations can be supported. We examine each of these in turn.

Human-computer interaction can take the form of no direct use at all, when external consultants are relied on to operate the GIS. The dominant form of human-machine interaction when community organizations use GIS is passive. Use is dictated by available maps and databases, and restricted to a fixed menu of GIS procedures determined by providers. Active use occurs when users are free to develop their own operations and classifications of given databases. Users who become knowledgeable about and comfortable with GIS learn to exploit the technology to its potential. They may then be able to avoid the expense of external GIS consultants, or can make sure consultants provide what the community wants. Pro-active use describes situations where users input and analyze their own information within the GIS, and may even attempt to transcend the limitations of GIS software for meeting community organizations' needs.

Researchers in the area of public-participation GIS have begun to clarify how current GIS technologies, which were not developed with community organizations in mind, may not be the most appropriate possible geographical information technology for the needs of such organizations. Some of these researchers have been seeking ways to extend the appropriateness of GIS for community organizations and grassroots groups by combining GIS with multimedia technologies, with sketch-mapping tools (c.f. Harris et al. 1995, Weiner et al. 1995), and with web-based interfaces. Even in the research community, this kind of pro-active use remains rare, and we are unaware of any community organization doing this.

The second aspect of communication structures involves patterns of communication within community organizations when they use GIS. Typically, a GIS user interface is individualistic: Only one user is logged on to the technology at a time, thereby controlling GIS operations. Such individualistic interfaces do not match the kinds of collective exchange of ideas or communicative action that are more typical of community organizations. Such organizations see themselves as strongly democratic institutions that avoid placing power in the hands of a few, and are not dominated by decision-making with well-defined goals in mind (Habermas 1984. For applications in planning, see Healey 1992, Fischer and Forester 1993). There are a number of experimental "collective spatial decision-making" human-computer interfaces, where different users sit at separate computer screens in different locations, and simultaneously manipulate the same GIS and databases (Couclelis and Monmonier 1995, Nyerges et al. 1997). Such collective human-computer interfaces may support and potentially enhance collaborative decision-making in community organizations, but these are rare even in academic environments.

The third aspect of communication structures is whether they support the free exchange of experiences with and results of GIS use between different community organizations. Community organizations employ an intra-organizational communication structure when they work independently in using GIS–whether they use an in-house GIS, a community-university partnership, or a public library. Organizations can tailor this use to their particular needs, but do not benefit from the experiences of other similarly placed organizations. Alternatively, community organizations participate in an inter-organizational communication structure if they have access to a collectively owned GIS center where they can share experiences and learn from one another. Installation of a collective spatial decision-making system in several community organizations would also create an inter-organizational communication structure. An inter-organizational communication structure might place restrictions on an organization's ability to custom design GIS use, since all partici-

pants would need to agree on some common protocols, but it would save unnecessary duplication of equipment, expertise, and effort. No community organization in the Twin Cities participates in an inter-organizational communication structure, but the Data Center in Milwaukee is one example of such a system in operation (see below).

A communication structure that is pro-active, collective, and inter-organizational holds certain advantages for community organizations relative to a passive, individualistic, and intra-organizational communication structure. The former can avoid unnecessary duplication of effort and promote mutual learning, but is more expensive and challenging to develop because it would require the organization to do much more than purchase a GIS "out of the box." The latter is cheaper and can also meet community needs; however, its use may constrain community action because of its focus on a narrower and more limited GIS communication structure.

The third dimension of difference, the geographical location of the GIS, refers to whether the technology can be accessed without leaving the neighborhood where the community organization is located. Location in the community (whether as an in-house GIS or as a local terminal connected to a distant GIS) maximizes physical access to the technology by community organization staff and community residents. This promotes direct use of GIS as a part of other organizational activities and makes it easier to tailor this use to local needs (although access over the Internet may involve additional constraints such as slow response times). Remote GIS locations, which members of the community organization must travel outside the neighborhood to utilize, have certain disadvantages. and would limit the number of organization members and residents who can use the GIS, separate its use from other activities, and are likely to support more standardized applications.

Assessing the Advantages and Disadvantages of Modes Of Provision

The advantages and disadvantages of the different modes of providing GIS to community organizations are discussed in this section. We suggest that the many specific advantages and disadvantages can be grouped broadly into two types: responsiveness to community organizations' needs, and financial, political, and human capital costs of implementation and maintenance.

Responsiveness attempts to capture the various ways in which a mode of provision can be flexible and sensitive to the particular contexts and needs of different organizations. Community organizations have had little influence over the development of currently available GISs, and their vision of GIS use is more participatory than that of many other user groups. Particular modes of provision will be more or less able to bridge such gaps between the technology and the organization, depending on their stakeholders, communication structures, and geographical location attributes.

The costs of access and use are very important because community organizations are often resource-poor, with limited financial, political, and human capital that can be devoted to GIS. Two aspects of these costs are particularly important. First, it is necessary to distinguish between individual costs to an organization and collective costs that result from unnecessary duplication across community organizations. Second, the costs for set-up must be distinguished from that of maintenance. The maintenance cost is particularly important, since community organizations are often faced with limited and rapidly changing and financial and human resources. For example, failure to plan for maintenance costs of a community-based GIS may result in it not being used after set-up. As with responsiveness, the costs accruing to community organizations will vary depending on the particular configurations associated with different modes.

A discussion follows on how different modes of provision, with different stakeholders, communication structures, and locational configurations, present different advantages and disadvantages for community organizations.

Central Spatial Data Distribution Facilities

The costs associated with using central spatial data distribution facilities are high in some ways and relatively low in others. Direct financial costs for users are typically low and are "pay as you go," so that community organizations do not need to make a large initial investment, as they would in an in-house community-based GIS. Because the facility is located outside the community, the users bear the time and financial costs of travel, a potential limitation for community organizations whose staff and members have transportation or time limitations. Further, because the organization is not developing in-house expertise, it must continue to invest resources in external expertise. The collective costs of providing GIS access through such a facility may be lower, however, because there is no duplication of equipment and expertise across communities. Additionally, such a centralized facility will likely be able to afford to gather and maintain a greater range of data and a larger number of maps at different scales and resolutions than could any single community organization.

Because stakeholders other than the community organization control such facilities, responsiveness to community organization needs is potentially lower. Community clients only have access to data and analyses that the facility chooses to provide, and a community's locally collected information often cannot be incorporated. In the case of the Minneapolis GIS Print Room, community organizations are not the primary clients, and some feel that the services and data provided are geared more toward the needs of city government clients. Responsiveness of this mode is also limited because community organizations typically have little opportunity to directly interact with the GIS or manipulate data themselves. If facility staff have little specific expertise with community organization needs, then communication difficulties between facility staff and clients may prevent clients from obtaining the information they seek. Finally, time constraints may limit the responsiveness of this mode of provision for community organizations. Organizers we interviewed

in the Minneapolis Community GIS Project, for instance, found that the 1- or 2-week period needed to obtain maps from the GIS Print Room undermined their need to quickly obtain geographic information.

GIS Facilities in Universities and Public Libraries

For publicly accessible GIS facilities in universities and public libraries, the costs of GIS provision are similar in many ways to those for central spatial data distribution facilities. Reliance on these facilities entails lower direct costs for community organizations because they can gain access to GIS without incurring the costs of obtaining and maintaining hardware, software, and data. Further, because the providers of these facilities typically are funded on a more stable basis, they can provide a more long-term GIS resource than community organizations. As with all facilities located outside a community, the staff and volunteers face time and transportation costs. In the case of the University of Minnesota's Automated Cartographic Information Center, community organizations must find staff or volunteers who can go to the facility during business hours. This is especially problematic when organizations rely heavily on volunteers with other full-time jobs. The centralized nature of public-access facilities in libraries lowers costs by reducing the need for duplication. Further, staff sometimes develop and disseminate expertise about how to solve standard problems.

The responsiveness of such facilities to community organizations' needs may be limited by the agendas of the stakeholders establishing and maintaining them, who determines the data that is made available, the analysis capabilities, and the level of advice or assistance offered to clients. Responsiveness does, however, depend on the mix of users, the mission of the institution, the attitudes of the staff, and the resources available. The ACIC has many community clients, and those running the facility have responded by providing community organizations with a wide range of data and analysis capabilities and with the option of incorporating their own data. Responsiveness in such facilities is also enhanced because users operate the GIS themselves, although the ability of community organizations to capitalize on this potential depends on the degree of assistance available at a facility and on their own expertise in utilizing GIS software.

Community-Based (In-House) GIS

The costs of a community-based GIS differ considerably from the previous two modes of provision. When a GIS is located within a community organization's office, there is a savings in time and financial costs of traveling outside the neighborhood. Notwithstanding these savings, community-based GIS is potentially the most costly option. Not only do individual organizations devote resources to obtaining and maintaining hardware, software, and data, and developing in-house expertise, but considerable unnecessary duplication of effort is likely across organizations. A community-based GIS may be at a disadvantage because of rapid turnover of staff and resident participants, unstable funding sources, and lack of expertise and training in GIS and spatial analysis. In the case of Minneapolis' Powderhorn Park Neighborhood Association, while the organization wanted volunteers to be involved in using their in-house GIS, it was unable to devote the time necessary to train an ever-changing array of potential participants without negatively impacting the organization's other activities. As a result, their GIS is used only by staff members, potentially limiting its utility to the organization as a whole.

The high costs are mitigated by the potentially high responsiveness of a community-based GIS. As the primary stakeholder, community organizations usually are in control of the data and analysis. With this influence over data and analysis options, as well as in-house location and direct use of the GIS by community organization users, this mode should support the provision of information for quick and flexible responses to neighborhood issues. This response potential was a major incentive for PPNA to pursue a community-based GIS. Staff and volunteers felt that their capacity to analyze and respond to changes or events in the neighborhood was limited by the extended period of time it often took for them to obtain maps and analysis through other locally available modes, such as the GIS Print Room.

The extent to which an organization can realize the potential responsiveness of a community-based GIS may depend also on its relationships with external stakeholders who provide hardware, software, data, training, or funding, and thereby can influence the organization's GIS efforts. For instance, most of the data that a community organization wishes to incorporate in its GIS come from government agencies, and community organizations often have difficulty convincing these agencies to release data to them. PPNA, for example, contacted many different city and county government offices and officials before finally obtaining digital data on housing issues to include in their database.

Finally, responsiveness and cost may be interrelated. The high costs associated with a community-based GIS may limit the actual responsiveness of this mode of provision. For example, to keep set-up costs low, PPNA hired a low-cost "no frills" software developer to design their database. This led to on-going software problems that limited the effectiveness of their GIS. The interface between the database and the purchased GIS software makes querying the data and creating maps very complicated, so it is used less than it might be otherwise. In addition, attempts to update the database with new data from government offices sometimes causes the database to crash, necessitating an enormous investment in staff time to correct problems.

University-Community Partnerships

Like some other modes of provision, university-community partnerships are advantageous because community organizations do not bear costs of training, software, hardware, and data. Overall, collective costs are higher than for some of the centralized modes, since these partnerships usually exist between a single university course or research project and a single community organization. In some instances, however, ongoing relationships can bring mutual benefits for both partners. In the case of our collaboration with Minneapolis' Phillips Neighborhood, the partners were

involved in both the Minneapolis Community GIS Project and the Phillips Neighborhood Environmental Inventory Project, and collaboration and mutual understanding improved over time.

University-community partnerships are potentially highly responsive. They are explicitly intended to meet specific community needs, so, in principle, the community should have the power to ensure that data and analyses are responsive to their needs. In practice, responsiveness also depends on the type of relationship between the partners, which in turn is influenced by their respective capacity and skills. Community partners usually do not directly use the GIS, so responsiveness may be limited in cases where either the community organization does not have the expertise to explain what is needed, or university partners do not know enough about the community to understand what is needed. Further, we have found that the practical difficulty of ensuring communication between busy community partners and students during coursework projects can also diminish responsiveness. Similar limitations may also occur in cases where community partners do not take an active in role in supervising and guiding the project.

Overall, the responsiveness of this mode of provision for meeting the needs of community organizations is complicated by the priorities of the university partner. University partners are subject to funding cycles or academic calendars that limit when and to what extent they can participate in partnerships with community organizations. University priorities other than community outreach, particularly meeting curricular and research goals, may diverge from community organization needs and undermine the ability of the partnership to adequately address the latter.

Internet Map Servers

The costs for community organizations associated with using Internet map servers are low compared to a community-based GIS and to some extent even central spatial data distribution facilities. Community organizations must purchase only the hardware and software necessary to access the Internet, costs that can be avoided by using public libraries or residents' home computers. Travel costs are eliminated, as is the duplication of GIS software that characterizes modes of provision such as community-based GIS, and information can be obtained at any time of day (presuming that the server hosting the Internet map site is reliable).

While costs are low, responsiveness to specific needs of community organizations is considerably lower as the community organization does not directly control the GIS. Community organizations potentially have ready access to a rich source of information, but this is filtered by those who design the site and is limited by the ability of GIS software to handle on-line active users. Sites differ, but in general are limited in the degree to which they enable users to actively manipulate data to fit their needs. Passive use dominates, and we are aware of no sites that support pro-active use–allowing GIS users to add their own data or software. Internet map servers typically offer limited advice or assistance and may be slow and unstable, and inexperienced users may have difficulty taking advantage of whatever capabilities a particular site may have.

Conclusion

In this article, we have developed a description and conceptualization of different modes of GIS provision for community organizations and a preliminary assessment of their efficacy. We argue that different modes of provision, characterized by varying forms of stakeholder-community relationships, communication structures, and geographic location of the GIS, enable different degrees of responsiveness to the specific needs of community organizations, and are associated with varying financial, political, and human capital costs for such organizations. It does not follow, however, that there is any single best mode of provision, because different community organizations face unique and variable situations and constraints. In our experience, community organizations do not treat different modes as discrete choices, but often draw simultaneously on alternative modes of provision, changing their strategies over time as their situation changes, and developing novel ways of accessing and using GIS and spatial data.

While the conceptual framework developed here abstracts from five modes of provision that we are familiar with in the Twin Cities, it can also be used to assess other approaches. One such alternative is Milwaukee's Data Center, a facility operated by The Nonprofit Center of Milwaukee, a consortium of non-profit organizations. The Data Center is intended to serve the collective GIS and spatial data needs of nonprofit and community organizations. From the perspective of our conceptual framework, a collaborative GIS center can lower both set-up and maintenance costs for participating organizations because several groups share these costs. This enables a larger range of data and services to be available to participating community organizations. These savings may outweigh the costs that are added because a collaborative GIS center is not necessarily located in the communities that use its services. This mode of provision has the potential to be highly responsive to community needs, assuming that such a center is designed to serve the particular needs of participating organizations. Such a center might also help community organizations develop expertise in GIS and spatial analysis and interpretation (Barndt and Craig 1994). Finally, this mode of provision has significant potential for inter-organizational communication, providing an opportunity for community organizations to collaborate and share experiences, potentially further enhancing their ability to mold the GIS and spatial data to their needs.

While collaborative GIS centers hold great promise as both an efficient and responsive mode of provision, their ability to serve community organizations' needs depends on a sufficient and stable funding base. In the case of Milwaukee's Data Center, member contributions and service fees are inadequate to cover the costs of providing the services requested (Michael Barndt, personal communication, May 2000). Such centers are thus in dire need of significant and sustained financial support from private foundations and government agencies.

The conceptual framework developed in this article has the normative potential to suggest other modes of provision, with distinct characteristics that may make them better suited for community organizations than any of those discussed here. Following the reasoning developed here, a new mode of provision would be particularly desirable if it were characterized by: external stakeholders with a long-term commitment to the community; cooperative relationships between stakeholders and community organizations; a communication structure which is pro-active, collective, and inter-organizational; and location within the community that wishes to use the mode of provision.

The foregoing assessment of the five different modes of provision, and of the Data Center model, can be expanded in future research in a number of ways. At present, this assessment is primarily based on our own research experiences and observations. This must be complemented by both studying community organizations using these modes, the subject of our ongoing research, and by the experiences of other researchers, whose familiarity with examples may reinforce or call into question the framework developed here. Analysis is also needed to examine ways in which different modes of provision might enhance or undermine democratic decision-making processes within community organizations, or alter the ability of such organizations to represent the diversity of viewpoints held by community members. The study of ways that community groups may be using GIS to foster increased involvement or influence in planning and decision-making can also contribute to our understanding of the changing roles and power of citizen groups in urban planning.

Another important area for further research concerns the legal and ethical issues associated with GIS use by community organizations. These issues include questions of liability in the use of GIS and distribution of spatial data, and issues of access to the spatial data collected by federal and local governments (Onsrud 1992a,b, Onsrud 1995, Sheppard et al. 1999). The use of GIS by community organizations also raises questions about who holds intellectual property rights over spatial information collected by the community, and concerns about the threats to the privacy of community members that may result from the use of GIS for neighborhood surveillance (c.f. Elwood and Leitner 1998). Community organizations may struggle over who determines what information is regarded as legitimate to include in a GIS database, as well as who has access to these data. Individual citizens, local governments, or the media might try to gain access to sensitive community-generated data, such as health information, which the community does not wish to release. These legal and ethical concerns may arise differently within various modes of provision, affecting community organizations and their constituents in different ways.

Clearly, this paper just begins to scratch the surface of a research agenda examining the utility and implications of GIS use by community organizations. While there are many questions that must be explored concerning its appropriateness for such social actors, the horse is already out of the barn. Community organizations are continuing to expand their use of GIS, making it essential to advance research that can help them comprehensively assess how best to make use of this technology in promoting community-based planning and grassroots democracy.

About the Authors

Helga Leitner received a Ph.D. from the University of Vienna. She is Professor of Geography at the University of Minnesota, and has also taught at the University of Vienna, University College London, and the University of Indonesia. Her current research interests are in urban planning and development, ethnic minorities, and immigration, GIS and society, and environmental justice. The author may be contacted at 481 Soc. Sci., 267 19th Ave. S, Minneapolis, MN 55455. (612) 625-9010. eqj@6139@umn.edu.

Sarah Elwood received a Ph.D. from the University of Minnesota. She is Assistant Professor of Geography at DePaul University. Her current research interests are in neighborhood planning and development, neighborhood use of information technologies, and public-participation GIS. Room 414 Soc Sci. 267 19th Ave. S, Minneapolis, MN 55455. (612) 625-6080. elwoo004@umn.edu.

Eric Sheppard received a Ph.D. from the University of Toronto. He is Professor of Geography at the University of Minnesota, and has also taught at the University of Vienna, University College London, and the University of Indonesia. His current research interests are in urban and regional economic development, the political economy of globalization, GIS and society, and environmental justice. Room 414 Soc. Sci. 267 19th Ave. S, Minneapolis, MN 55455. (612) 625-5840. shepp001@umn.edu.

Susanna McMaster received a Ph.D. from Syracuse University. She has taught at Macalester College Vienna, University College London, and the University of Indonesia. Her current research interests are in GIS, GIS and society, and environmental justice. (651) 696-6126. mcmaster@macalester.edu.

Robert McMaster received a Ph.D. from the University of Kansas. He is Professor of Geography at the University of Minnesota, and has also taught at Syracuse University and the University of California at Los Angeles. His current research interests are in GIS and cartography, the history of cartography, GIS and society, and environmental justice. Room 414 Soc Sci. 267 19th Ave. S, Minneapolis, MN 55455. (612) 625-9883. mcmaster@umn.edu.

Bibliography

Aitken, S. and S. Michel, 1995, Who Contrives the 'Real' in GIS? Geographic Information, Planning, and Critical Theory. *Cartography and Geographic Information Systems*, 22(1), 17-29.

Barndt, M., 1998, Public Participation GIS–Barriers to Implementation. *Cartography and Geographic Information Systems*, 25(2), 105-112.

Barndt, M. and W. Craig, 1994, Data Providers Empower Community GIS Efforts. *GIS World,* 7(7), 49-51.

Baum, H, 1999, Community Organizations Recruiting Community Participation: Predicaments in Planning. *Journal of Planning Education and Research* 18, 187-199.

Baum, H., 1997, *The Organization of Hope: Communities Planning Themselves* (Albany, NY: SUNY Press).

Campbell, H. and I. Masser, 1995, *GIS and Organizations: How Effective are GIS in Practice?* (London: Taylor and Francis).

Couclelis, H., and M. Monmonier, 1995, Using SUSS to Resolve NIMBY: How Spatial Understanding Support Systems Can Help With the 'Not In My Back Yard' Syndrome. *Geographical Systems*, 2(2), 83-101.

Craig, W., 1994, Data to People: North American Efforts to Empower Communities with Data and Information. *AGI94 Proceedings, Association of Geographic Information,* London, 1.1.1-1.1.5.

Elwood, S., 2000, *Information for Change: The Social and Political Implications of Geographic Information Technologies.* Ph.D. dissertation, Department of Geography, University of Minnesota.

Elwood, S. and H. Leitner, 1998, GIS and Community-Based Planning: Exploring the Diversity of Neighborhood Perspectives and Needs. *Cartography and Geographic Information Systems* 25(2), 77-88.

Fischer, F. and J. Forester (Eds.), 1993, *The Argumentative Turn in Planning Theory* (Durham, NC: Duke University Press).

Gans, H., 1991, *People, Plans, and Policies: Essays on Poverty, Racism, and Other National Urban Problems* (New York, NY: Columbia University Press).

Grant, J., 1994, *The Drama of Democracy: Contention and Dispute in Community Planning* (Toronto: University of Toronto Press).

Habermas, J., 1984, *The Theory of Communicative Action, Vol. 1: Reason and the Rationalization of Society* (Cambridge, MA: MIT Press).

Harris, T. and D. Weiner, 1998, Empowerment, Marginalization and 'Community-Integrated' GIS. *Cartography and Geographic Information Systems*, 25(2), 67-76.

Harris, T.M., D. Weiner, T. Warner, and R. Levin, 1995, Pursuing Social Goals through Participatory GIS: Redressing South Africa's Historical Political Ecology. In Pickles, J. (Ed.), *Ground Truth: The Social Implications of Geographic Information Systems,* (New York: Guilford Press), 196-222.

Healey, P., 1997, *Collaborative Planning: Shaping Places in Fragmented Societies* (Vancouver: University of British Columbia).

Healey, P., 1992, Planning Through Debate. *Town Planning Review*, 63, 143.

Heikkela, E., 1998, GIS is Dead; Long Live GIS! *Journal of the American Planning Association,* 64(4), 350-360.

Klosterman, R., 1998, Farewell to the Computer Reports. *Journal of the American Planning Association,* 64(4), 470-474.

Nyerges, T., Barndt and K. Brooks, 1997, Public Participation Geographic Information Systems. *ACSM/M. ASPRS Annual Convention and Exposition Technical Papers*, Bethesda, MD, 224-233.

Obermeyer, N.J., 1998, The Evolution of Public Participation GIS. *Cartography and Geographic Information Systems*, 25(2), 65-66.

Obermeyer, N. and J. Pinto, 1994, *Managing Geographic Information Systems* (NY: Guilford).

Onsrud, H.J., 1995, The Role of Law in Impeding and Facilitating the Sharing of Geographic Information. In Onsrud, H.J. and G. Rushton (Eds.), *Sharing Geographic Information Systems,* (New Brunswick, NJ: Center for Urban Policy Research), 292-306.

Onsrud, H.J., 1992a, In Support of Cost Recovery for Publicly Held Geographic Information. *GIS Law,* 1(2), 1-7.

Onsrud, H.J., 1992b, In Support of Open Access for Publicly Held Geographic Information. *GIS Law,* 1(1), 3-6.

Onsrud, H.J. and J.K. Pinto, 1993, Evaluating Correlates of GIS Adoption Success and the Decision Process of GIS Acquisition. *Journal of Urban and Regional Information Systems,* 5(1), 18-39.

Onsrud, H.J. and J.K. Pinto, 1991, Diffusion of Geographic Information Innovations. *International Journal of Geographic Information Systems,* 5(4), 447-467.

Pickles, J., 1995, Representations in an Electronic Age: Geography, GIS, and Democracy. In Pickles, J. (Ed.), *Ground Truth: The Societal Implications of Geographic Information Systems* (New York: Guildford), 1-30.

Pinto, J.K. and H.J. Onsrud, 1997, In Search of the Dependent Variable: Toward Synthesis in GIS Implementation Research. In Craglia, J. and H. Couclelis (Eds.), *Geographic Information Research: Bridging the Atlantic* (London: Taylor and Francis), 129-145

Ramasubramanian, L., 1998, *Knowledge Production and Use in Community-Based Organizations: Examining the Impacts and Influence of Information Technologies.* Ph.D. Thesis, University of Wisconsin-Milwaukee.

Sandercock, L., 1998, *Towards Cosmopolis: Planning for Multicultural Cities* (New York: John Wiley).

Sawicki, D. and W. Craig, 1996, Democratization of Data: Bridging the Gap for Community Groups. *Journal of the American Planning Association*, 62(4), 512-523.

Sheppard, E., 1995, GIS and Society: Towards a Research Agenda. *Cartography and Geographic Information Systems*, 22(1), 5-16.

Sheppard, E., H. Couclelis, S. Graham, J.W. Harrington and H. Onsrud, 1999, Geographies of the Information Society. *International Journal of Geographic Information Science*, 13(8), 797-821.

Sieber, R., 1997, *Computers in the Grassroots: Environmentalists, Geographic Information Systems, and Public Policy.* Ph.D. Dissertation, Department of Urban Planning and Policy Development, Rutgers University.

State Cartographer's Office, 1998, *Wisconsin Mapping Bulletin*, 24(4), October.

Tauxe, C., 1995, Marginalizing Public Participation in Local Planning: An Ethnographic Account. *Journal of the American Planning Association*, 61(4), 471-481.

U.S. Department of Housing and Urban Development, 1995, *A New Way to Connect: Community Connections Software*. Washington, D.C.: Office of Community Planning and Development, Community Connections Program, U.S. Department of Housing and Urban Development.

Van Tulder, R. and W. Ruigrok, 1997, The Nature of Institutional Change: Managing Rival Dependencies. In Amin, A. and J. Hausner (Eds.) *Beyond Market and Hierarchy: Interactive governance and social complexity* (Cheltenham, UK: E. Elgar), 129-158.

Weiner, D., T. Warner, T. Harris and R. Levin, 1995, Apartheid Representations in a Digital Landscape: GIS, Remote Sensing, and Local Knowledge in Kiepersol, South Africa. *Cartography and Geographic Information Systems*, 22(1), 30-44.