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Contents

Refereed

On the Cover:

No matter the hemisphere, online information technologies have become essential tools for urban planning. The personal computer and internet support information sharing and participatory decision making in the planning process. Good government used to mean the trains would run on time. The populace was a distant and passive body represented by a handful of active and motivated mouthpieces. Making decisions with less information was risky but fast. In the era of the internet, the speed and delivery of government services has thrust Australian local government into a new era of community planning and access. The amount of information readily available to local governments has exploded. The challenge is developing infrastructure to meet new demands. The new problem is not a lack of information but rather knowing how to coordinate existing thinking with the influx of data available at the push of a button. These issues are outlined in an article by Tan Yigitcanlar entitled, "Australian Local Governments' Practice and Prospects with Online Planning." The article underlines the importance of online planning and e-participation, examines household use of information technology, and discusses the digital divide problem. It also explores Australian local governments' potential and experiences in online planning and arranges them into clusters of those who are successfully adapting and those that aren't.

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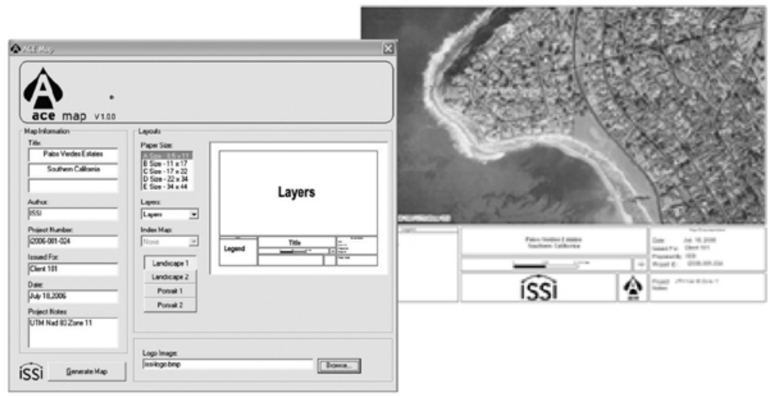

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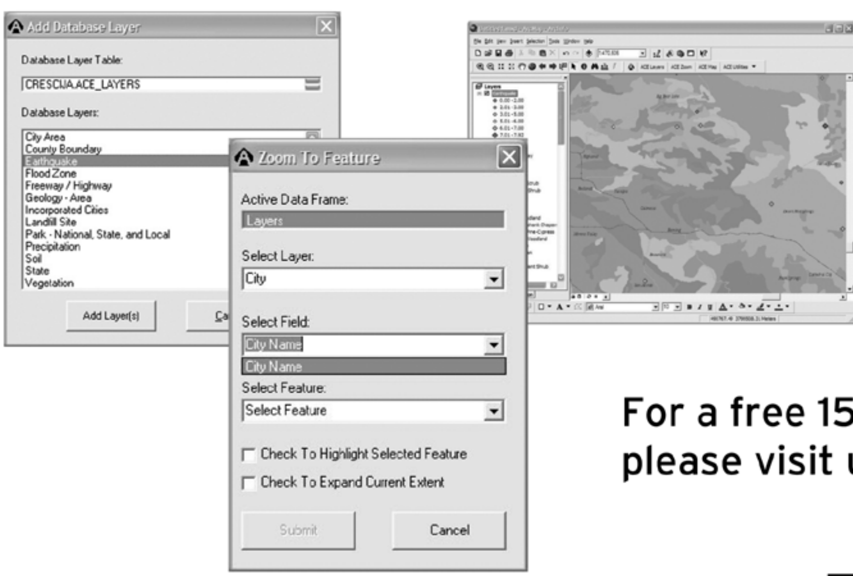

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Foreword

When I was asked whether I would be willing to become editor of the *URISA Journal,* I was first surprised and then excited about the prospect. Surprised because I have the reputation of being a rather theoretically oriented person; excited because I see this journal as one of the more relevant ones in the GIScience scene. I will elaborate a little more on the latter because it also gives me an opportunity to outline my vision for future directions.

When Harlan Onsrud became editor of this journal, he revolutionized the review and production process and opened the journal to a new international audience. Steve Ventura built on the innovations and managed an ever-increasing number of thematic and section editors, who represent the ever-broadening realm of the journal. Much of this would not have been possible without the able support of Scott Grams in the URISA main office, who as production editor relieves us of much of the technical nitty-gritty.

Looking at the journal's mission statement (http://urisa.org/journal_mission), it is easy to be intimidated by the scope, which goes far beyond that of any other in the field. Without wanting to alienate any of our readers, I feel that somebody new to the journal is likely to be dissuaged from considering this journal as his or her home. Rather than adding even more disciplines, I would therefore like to look at the functional roles that *URISA Journal* authors and readers have. A windfall of this approach is the identification of what exactly it is that distinguished this journal from its competitors.

URISA Journal readers are professionals and high-level managers. They tend to work for local and regional authorities or private consultancies who, in turn, work for such authorities on territorial aspects of their respective employers. They typically are decision makers, shaping or implementing policy. As such, their work has a high degree of relevance. I contrast that with the typical academic and the journals that they tend to read, which are generally somewhat removed from the real world. Mind you, I am an academic myself, but, like my predecessor, Steve, I am increasingly likely to be seen in company of a spatially aware professional than with a colleague at varsity.

During my career, I have collaborated with colleagues from the Auckland (NZ) Regional Council, the Milwaukee Mayor's office, the Federal Geographic Data Committee, HAZUS user groups, the Wildlife Conservation Society, and, as of late, the New York City Metropolitan Transportation Council. Each of these groups had URISA members among them (or as in the case of Auckland, our sister organization, AURISA), and our journal circulates well within these groups. I appreciate the high level of professionalism within these groups, which is exactly what, in turn, attracts them to the *URISA Journal.*

Many of the most exciting articles come from practitioners. Yet, they are not mere rah-rah stories of implementations or the kind of vendor-sponsored articles that we find in trade magazines. There is a place for each of those, but the *URISA Journal* is in a unique position in that the articles published here build on such practical experience and then take the additional step to abstract and provide a framework for wider applicability. All this is captured in an exemplary way in the title of Caron and Bedard's 2002 contribution to our journal, "**Lessons learned from case studies on the implementation of geospatial information technologies.**"

In this spirit, I would like to invite you to share your reflections with us. In particular, I am interested in and would like to create a special issue of your Web 2.0 experiences. Other topics that I am keen on seeing submissions about include:

- Efforts to increase infrastructure resilience in high-density areas. Japan has a lot to teach us here, but I could also see submissions from Latin America.
- Water management. Water in the long run is probably going to be the most precious commodity, and I am looking for articles that cover a wide range of aspects, from territorial disputes to recycling and fair use.
- The challenges of dealing with high-resolution spatial data have so far attracted much less attention than the promises

of the data providers. What experiences have you had, for example, with applying traditional geocoding algorithms to highly accurate parcel-level data?

Do not feel discouraged if your pet topic is not listed. As the new editor, I am curious to hear from you. Please react to this or any other *URISA Journal* article and share with me your wishes or visions for the journal. There are two ways to do this. One is by traditional e-mail; I would also like to point out to you the "comment" facility for our online articles. When you log onto our Web site, you can post and read the comments on each article. This is but one of the many new options of the journal's online presence; I encourage you to subscribe to our RSS feeds, for instance. Kudos to Scott Grams, who facilitated the revamping of what already was one of the most sophisticated journal Web sites!

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Australian Local Governments' Practice and Prospects with Online Planning

Tan Yigitcanlar

Abstract: *Online information technologies are becoming essential tools for urban planning as they support information sharing and participatory decision making in the planning process. Therefore this paper underlines the importance of online planning and e-participation, examines household use of information technology, and discusses the digital divide problem. This paper also explores Australian local governments' potential and experiences in online planning. It scrutinizes existing infrastructures of local councils as well as their willingness to adopt the Internet and geographic information systems in their planning processes. This research clusters local government areas in terms of their potentials in the implementation of online planning. This clustering would lead Australian governments to develop policies on where to start and where to extend online planning next. The paper concludes with introducing online planning examples and initiatives from Australia.*

INTRODUCTION

Public participation is a very important part of the planning process that provides opportunities and encouragement for the public to express their views (Burke 1979, Day 1997, Beder 1999, Campbell and Marshall 2000, Brody et al. 2003). Public involvement in planning, however, requires a system to be accessible to all. To achieve broad participation, authorities will have to check their arrangements for public access to planning information and services. These arrangements include effective use of information and communication technologies (ICTs). Today, ICTs are providing new opportunities for public involvement in urban planning and also addressing the digital divide to make sure everyone can take part in the planning process (Innes and Booher 2000, Jankowski and Nyerges 2001, Craig 2002).

Online planning—sometimes referred to as *Internet-assisted urban planning*—is a new frontier for the planning discipline. It creates a new platform for planning operations and processes, and increases the opportunity for public participation. Online planning offers people access to a seamless record of the progress and approval of planning proposals and policies (Shiode 2000, McGinn 2001).

The Internet is the main medium of information exchange for online planning, and geographic information systems (GIS) are another significant technology that plays an important part in online planning. A decade ago, Pickles (1995) stated that GIS technology is beyond the reach of ordinary citizens, because GIS and spatial data are expensive and require high levels of training for competent use. Fortunately, with the substantial decrease in technology costs and introduction of Internet GIS, online data and analysis tools are becoming widely accessible to the public. Internet GIS applications increase public access to information and promote active participation in the planning process (Ceccato and Snickars. 2000, Kingston et al. 2000). Schiffer (1995) saw the promise of online planning, and according to Carver (2003), use of Internet GIS for planning is a step in the right direction: that of citizen empowerment through greater involvement and openness and accountability on behalf of decision makers. Thus, planning benefiting from the Internet and GIS can help local authorities organize planning schemes to involve residents' interaction with their planning processes.

This paper examines Australian local governments' potential and experiences in implementing online planning. In Australia, local councils have statutory powers over land-use zoning and the development approval processes and they are obligated to develop and implement strategic and local plans. This paper considers the extent to which those local councils are willing to embrace ICTs as planning tools, and the extent to which households might be ready to access new computer technologies.

In this research the following questions are considered: (a) What are the patterns of computer and the Internet use across households? (b) What might be done to narrow the digital divide? (c) What are current local government policies, capabilities, and projects with respect to online planning? (d) What are the potentials of local government areas (LGAs) in implementing online planning?

The research reported here is based on primary data collection and analysis, and secondary data analysis.

Primary data collection and analysis involved conducting a survey of planning officers in Australia's local councils to obtain information on the extent to which they are making use or plan to make use of ICTs to support online planning. The results of that survey are used to assess the potential and willingness of local governments to adopt ICTs for online planning.

Secondary data was used to ascertain the degree to which local councils are using Internet in their planning departments. This was carried out through a search of council Web sites. Secondary data analysis also focused on using Australian Bureau of Statistics (ABS) 2001 Census data to conduct a spatial and demographic analysis of ICT adoption by households in LGAs in Australia.

This paper discusses the following issues of online planning:

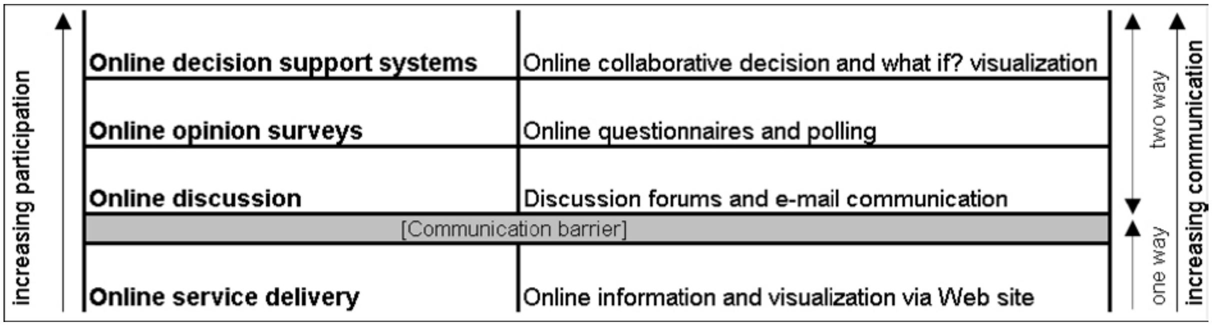

Figure 1. Online planning ladder (adopted from Smyth 2001)

e-participation, the digital divide, and information technology usage both across local councils in LGAs and by households within those LGAs. It then explores local councils' experiences in online planning.

ONLINE PLANNING AND E-PARTICIPATION

ICTs have been part of the planning system since the introduction of the mainframe computer in the 1960s. In terms of computational use for public participation, however, it is a relatively new phenomenon that focuses on visualization and analysis using GIS. Access to and participation in use of geographic information are important conditions when communities or societies at large address common problems in their living environments. Access to geographic information is both a necessary and possibly an enabling condition for participation in its use (De Man 2003). At that point, ICTs and explicitly the Internet are seen as breaking down barriers to participation, principally those concerning accessibility to geographic information.

Many planning departments are now using the Internet's interactive features to create a place for focused discussion and information exchange on the planning schemes (Yigitcanlar et al. 2003). The Internet together with GIS launches a channel to get mass participation in spatial referenced decision making (Jankowski and Stasik 1997, Leitner et al. 2000). Internet GIS is beginning to have a significant impact on the communities that participate in it (Plewe 1997, Batty 1998, Craig 1998, Peng and Tsou 2003).

The new form of public participation, which is called e-participation and is based around ICTs, has the power to enable participation in a variety of levels for stakeholders and the public (Carver et al. 2001, Ghose and Huxhol 2001). Online planning and e-participation occurs at several different levels (Figure 1). The bottom rung of the online planning ladder represents online (planning) service delivery. The flow of information is essentially one way, from server to client. Further up the ladder, the communication becomes bidirectional, making participation more interactive through sharing information, ideas, and feedback (Carver 2003). When it is implemented at the two-way communication level, online planning is a progress of getting common consensus about particular decision making. Traditional participation methods often diminish the range of participants. By online planning, many more residents can have the opportunity to participate in prioritizing potential development or decisions. Not only does online planning increase the potential number of participants in the planning process, but it further democratizes the participatory process (Huxol 2001). By creating online systems, the highly political issue of prioritizing planning and development can be brought into the privacy of residents' homes, where they can voice their opinions equally.

The Royal Town Planning Institute (2001, 40-41) underlines the importance of online planning in its report on modernizing local government:

> Local councils have a task to prepare community strategies which will engage the commitment and participation of the public as partners in decision making. This is a strategic partnership for the process of preparing local development plans collaboratively. To provide this partnership and collaborative planning services local governments should grasp opportunities being developed for online planning. This means more than simply offering information and standard advice in an electronic form; it can also mean a change in the relationship between professional staff and the public. Members of the community will expect to make contact with planners more easily and directly through the new channels of ICTs. This will require an even stronger customer focus by planners, with collaboration rather than aloof professional distance becoming the norm.

Large numbers of local governments abroad have begun to explore ways of taking the challenge of participatory planning in setting policy and budgetary priorities more seriously by using online technologies. The Canadian city of Guelph, for example, has implemented an impressively comprehensive and inclusive city planning strategy that draws on an extensive array of techniques for harnessing the experience and expertise of a wide range of citizens. This includes a particular emphasis on involving those who would not normally be participants in such discussions

(Wiseman 2003, Guelph City Council 2004).

In Australia, the most creative examples of participatory community planning strategies have been driven by local governments. For example, the city of Port Phillip, Victoria, has applied an online participatory planning strategy for identifying and prioritizing community and social indicators and using these to guide policy and resource allocation priorities. According to Wiseman (2003), another important progress is the recent reforms to the Victorian local government legislation. Before these reforms there was no legislative requirement for local governments to engage in participatory planning. Therefore, these reforms will provide further encouragement for this process by making it mandatory for local governments to conduct regular participatory processes. These processes will identify local priorities and progress measures by benefiting from online services such as local e-government (Yigitcanlar 2003).

Online planning does not only provide information, but it also supports consultation processes that encourage active participation of citizens in considering and establishing planning policies. When applying ICTs to planning, however, local authorities need to carefully consider and address the digital divide.

THE DIGITAL DIVIDE

The term *digital divide* is used to describe the patterns of unequal access to information technology that surfaced during the 1990s (McNeal 2003). It is also used as a term to indicate social exclusion in the online world as we move to the knowledge economy/society (Woodbury and Thompson 1999, Graham 2002, Stimson 2002). Most of the available literature suggests that socioeconomic status and demographic characteristics determine the frequency of use of ICTs (Hoffman and Novak 2000). In particular, issues of income and education are often seen as being important, while age and ethnic background may also be issues (The National Office for the Information Economy 2002, Van derMeer and Van Winden 2003). An important geographic component may also exist.

The concept of the digital divide is generally understood as a multidimensional phenomenon encompassing three distinct aspects: (1) the global divide, (2) the social divide, and (3) the democratic divide (Norris 2001). Likewise, Mossberger et al. (2003) categorized the digital divides as: (1) the access divide, (2) the skills divide, (3) the economic opportunity divide, and (4) the democratic divide.

The digital divide is becoming more of a recognized reality as technology makes phenomenal progress and online planning and local e-government applications are becoming popular in the new information age. Graham (2002, 37) says that:

> Even in advanced industrial nations with rapid maturing [I]nternet markets, whole sections of the urban population fail to benefit from the skills, education, equipment, infrastructure, capital, finance and support necessary to go and remain online. This is so at precisely the time when being online is becoming ever-more critical to access key resources, information, public services and employment opportunities.

The various demographic dimensions, along which the digital divide runs, represent a map of how social power is distributed. No matter where they are located, those who have higher incomes have greater access to, and are more likely to use, the Internet. Urban dwellers are usually better connected to electronic media than rural dwellers are. Those with more education often have both higher incomes and better connectivity. Trying to close the digital divide can be interpreted as one form of economic redistribution. Riley (2004, 18) argues that "narrowing the digital divide is only a matter of time" and asks:

> Prior programs of a Keynesian type have successfully extended other forms of infrastructure—electricity, sewage, education, telephone—from the upper classes to the entire population. Are there some significant differences between [I]nternet connectivity and these prior forms of infrastructure extension that precludes the digital divide from being treated in the same way as the provision of roads or sewers?

The digital divide is a complex issue with no singular cause or effect. Unfortunately, new technologies alone will not suffice to close the digital divide, because they heavily depend on physical and human capital, and the general economic policy environment (Digital Divide Network 2003). While online planning provides many opportunities for local authorities to serve citizens more effectively, it also runs the risk of widening existing inequalities and making non-IT users second-class citizens.

The first step in handling the digital gap is to understand the breadth and depth of any cultural, racial, education, knowledge, or literary divide that exists in any given jurisdiction. It is incumbent on governments to bridge these divides and ensure that there are no inequities between those who have the capacity to engage in online activity with governments and those who do not have access or do not wish to participate in the online world (Riley 2004).

The Organization for Economic Cooperation and Development (OECD) (2001) states that apart from general approaches in reducing the digital divide such as extending the infrastructure, skills, and information, it will be especially important to offer low-cost access. With computers and the Internet access available at public institutions (libraries, post offices, local and regional government facilities, schools, etc.), individuals can build up familiarity with information technology and develop important relevant skills. The provision of low-cost and subsidized access in schools, for example, will help to establish sound fundamentals for computer literacy of the future workforce and will improve the diffusion of decisive knowledge for the new economy. This diffusion of knowledge is an important aspect of developing successful online planning.

Digital Divide Network (2003 :3) underlines that addressing the digital divide requires a multifaceted approach, involving:

(a) Affordable access to information tools for the elderly, the

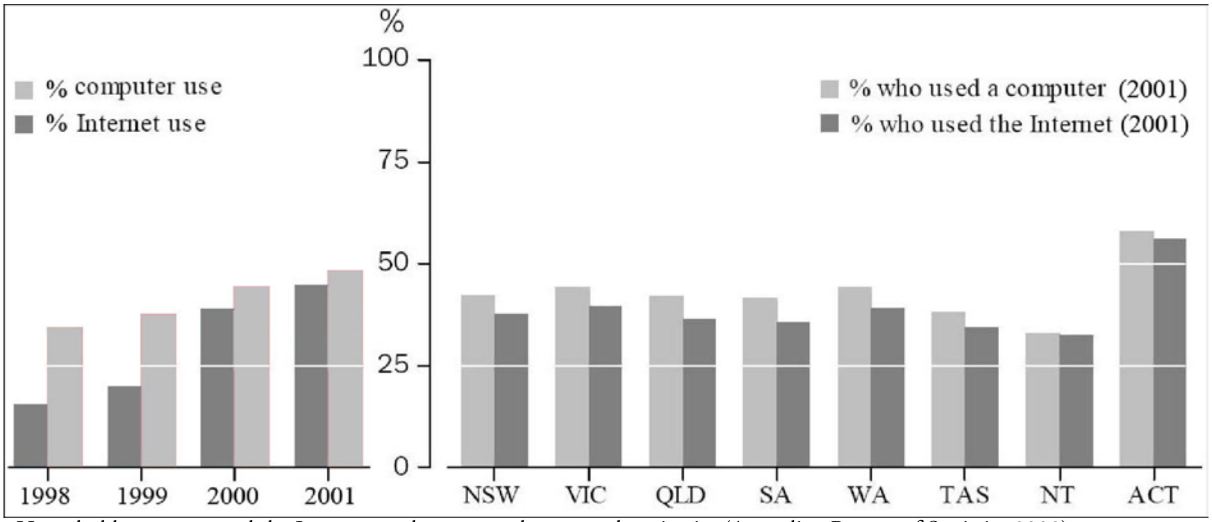

Figure 2. Household computer and the Internet use by years and states and territories (Australian Bureau of Statistics 2002)

poor, the disabled, and those living in rural areas; (b) Economic development of communities developing an infrastructure of telecommunications facilities and cultivating a well-trained workforce so that communities can remain competitive in attracting and retaining businesses; (c) Internet content that is relevant to and produced by communities addressing the availability of community-relevant information, overcoming language and literacy barriers, and promoting the diversity of cultural voices; and (d) A society devoted to lifelong learning developing the learning skills which will enable all generations to adapt to constantly changing times.

International practices have shown that many citizens currently cannot participate in the planning process, and as online planning becomes more pervasive, they will increasingly be left behind and become disenfranchised (Kennard 2001). For any online planning project to be successful, therefore, some degree of community development is necessary. The real success of online planning comes from developing policies and programs for: (a) understanding the differences among the public; (b) taking various public opinions and needs into consideration; (c) adding them into decision-making processes; and (d) fine-tuning online planning for a wider individual and community participation (Kuttan and Peters 2003). Consequently, only by understanding the needs of the residents and addressing the digital divide will local governments be able to realize the true vision of online planning.

AUSTRALIAN LGAS' POTENTIAL AND EXPERIENCES IN ONLINE PLANNING

Household Use of Information Technology

An objective of the research was to find a way to assess factors that might influence the development and use of online planning in LGAs. Consequently, important considerations are: (a) who has access to computers and the Internet; (b) how people use those technologies; (c) people's attitudes toward them; and (d) sharing information on the Internet. If an insufficient number of people use and feel comfortable with computers and the Internet systems, then moving planning services to an online mode may be questioned.

The 2001 Census data does not provide information regarding people's attitudes towards ICT utilization, although it does provide some information concerning the extent of Internet and computer use. That data has been analyzed to identify those factors affecting computer and the Internet use. Variables such as age, gender, education, occupation, geographic location, and income were considered. The 2001 Census data, together with other spatial datasets, was examined using SPSS and GIS analytical tools to develop basic profiles of computer and Internet users by households in LGAs.

Socioeconomic and demographic differences in the use of computers and the Internet are important because the ability to use these technologies has become increasingly critical to decision support in planning and development. In Australia, in the past few years, there has been a rapid increase in computer and the Internet use, not only in homes, but also at the workplace, schools, and other locations. Broadband connections, available principally through cable modems and digital subscriber lines, are making higher-speed connections available to an increasing number of Australians and expanding options for online usage. Not surprisingly as a result, household computer and the Internet use has increased substantially across the Australian states and territories (Figure 2).

Computer use has increased substantially in the past few years. As indicated by the 2001 Census, almost half of the population (43.1percent) used a computer. As the Australian Bureau of Statistics (2003) indicates, the Australian Capital Territory (ACT) had the highest rate of computer use (58.0 percent). The income category with the largest number of respondents in the ACT was the upper-middle-income category ($1,000 to $1,499 per week), while the income category with the largest number of respondents across Australia was the low-income category ($200 to $299). Because Canberra is the nation's capital city, education and income levels are remarkably high in ACT. Also, the larger proportion of students (31.4 percent) in ACT than the national average (26.1 percent) may be another reason for the higher-than-average use of computers.

The Northern Territory (NT) recorded the lowest reported use of personal computers (32.9 percent). This may be because the average income in NT is quite low (the largest number of people responded that their income was $160 to $199). Another reason for the low reported use of computers in NT could be the relatively large proportion of indigenous people (25.8 percent of the population compared to 1 percent to 9 percent in the other states) (Australian Bureau of Statistics 2003).

Australia is a nation where more and more people are going online everyday. Individuals continue to expand their use of computers and the Internet. As of 2001, 38.1 percent of the population had used the Internet or e-mail. Some 84.6 percent of those who used a computer also used the Internet. The Internet use in ACT was 54.1 percent and in NT was 31.8 percent, where the national average was 36.5 percent. The rates of computer and Internet use are varied by states and territories (Australian Bureau of Statistics 2003).

In general, the analysis of 2001 Census data has shown that Australian households are embracing technology. However, its use is varied in different localities and not every household has a similar attitude in using or accessing these technologies.

To determine the potential of online planning use among households in LGAs, this research grouped LGAs under three categories in regard to their household use of computers and the Internet: where computer and the Internet use is below 20 percent, it is referred to as "low"; where it is between 20 percent and 40 percent it is "medium"; and where it is equal to and more than 40 percent it is "high."

About 13 percent (13.1) of LGAs are recorded as LGAs with "high" competence of households in using computers and the Internet, 79.4 percent of them as "medium," and only 7.4 percent of them as "low" (Table 1). Figure 3 illustrates the results of the GIS analysis that combines both computer and Internet use and assigns an accessibility level for LGAs. This analysis showed that computers and the Internet technology are accessible to at least more than one-fifth of the population in most LGAs (92.5 percent) apart from some remote areas of the country.

This analysis on household characteristics in LGAs has shown that households with children, those with higher incomes, and those in metropolitan areas or large regional cities were more likely to have access to computers and the Internet. Also, users are more likely to be young, male, better educated, more affluent, urban, and not members of a racial or ethnic minority group than the population as a whole.

	High	Medium	Low
Metropolitan city councils (%)	47.0	13.7	0.0
Metropolitan town or shire councils (%)	42.2	4.4	0.0
Regional city councils (%)	3.6	16.5	6.4
Regional town or shire councils (%)	7.2	65.3	93.6
All councils (%)	13.1	79.4	7.4

Table 1. Household use of information technology by the local council's size and location

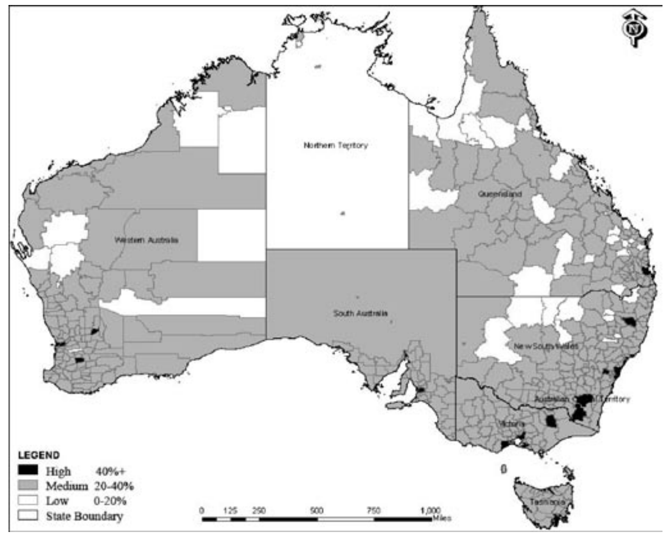

Figure 3. Household computer and the Internet use across LGAs

Local Councils' Use of Information Technology

To analyze local councils' use of information technology, a survey with local council planning officials was conducted to provide primary data in determining their potential in developing and adopting online planning. This survey was carried out during August of 2003. The questionnaire was e-mailed or mailed directly to the chief planning officers of all local planning authorities in Australia. In territories (i.e., ACT and NT), local governments are not responsible for planning and development tasks. Therefore, in ACT and NT, planning departments of the territory governments were invited to respond. The use of ICTs by state governments and planners in the private and academic sectors falls outside the scope of the survey.

In essence, the survey sought to ascertain the extent to which planning authorities are using relevant ICTs—GIS and the Internet. It sought to find what stage they had reached at the implementation in online planning and what factors were inhibiting progress. Respondents were asked to provide brief details of the technical environment in terms of hardware, networks, and software; the geographical data in use or being captured; and the organizational context for information provision in planning. The scope of the survey also included planning authorities' commitments and plans for the future. Out of 626 planning authorities, 383 (61.2 percent) responded to this survey (Figure 4).

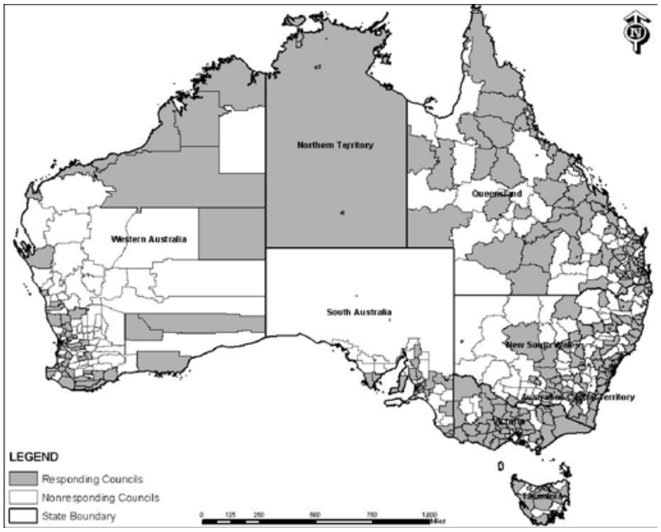

Figure 4. Responding local councils

	Number of councils	Number of responding councils	Response rate (%)
Metropolitan councils	222	116	52.3
Regional councils	404	267	66.1
Large (city) size councils	199	125	62.8
Medium or small (town/shire) size councils	427	258	60.4
Total	626	383	61.2

Note: Two territory planning departments are included in the Metropolitan city councils category

Table 2. Number and percentage of the responding local councils by their size and location

	Metropolitan city councils (%)	Metropolitan town or shire councils (%)	Regional city councils (%)	Regional town or shire councils (%)	All local councils (%)
Online decision support systems	15.9	18.4	14.6	11.4	13.6
Online opinion surveys	10.1	10.5	12.5	11.9	11.5
Online discussion	75.4	71.1	77.1	59.7	66.8
Online service delivery	87.0	84.2	87.5	93.8	90.3

Table 3. Local councils' choice of online planning level

	Metropolitan city councils (%)	Metropolitan town or shire councils (%)	Regional city councils (%)	Regional town or shire councils (%)	All local councils (%)
Digital dataset and map use for planning	94.6	90.5	98.0	84.7	89.0
Established GIS capacity (hardware, software, network, staff)	90.5	85.7	92.2	74.5	81.2
Utilizing GIS in the planning process	100.0	94.4	97.9	85.3	91.4
In-house digital data production	86.6	80.6	91.7	73.9	80.1
Digital planning information distribution	80.0	83.3	94.9	62.2	73.8
Planning information sharing with the public via Web sites	53.3	46.7	38.5	16.5	32.0
Planning information sharing with the public via Internet GIS	16.7	6.7	20.5	8.7	12.1

Table 4. Local councils' ICT utilization

Additional information is collected for each responding council either by visiting its Web site or by telephone interviews. In terms of core office applications, all the councils have fully developed word-processing, spreadsheet, and presentation packages. *Access to the Internet is pervasive,* and the analysis found that more than three-quarters of the councils have Web sites and fully operational e-mail (80.5 percent). *However, a digital divide continues to exist where some remote and smaller local governments lack high-speed broadband connections or have no connection to the Internet at all.*

In terms of legislative obligation within Australia, there is no direct regulation to mandate local councils to disseminate their planning information on the Internet. However, planning acts of each state require that copies of all planning schemes for every local government must be kept open for public inspection. Those acts indirectly encourage a vision for placing all planning schemes and related information on the Internet to foster public participation in urban planning.

Local councils are grouped under four categories to observe the digital divide among metropolitan and regional, large, medium-size, and small councils according to their location, population, and administration sizes. This grouping consists of: (a) metropolitan city councils (population > 50K), (b) metropolitan town or shire councils (population < 50K), (c) regional city councils (population > 25K), and (d) regional town or shire councils (population < 25K). The response rates of metropolitan councils were lower than regional councils', and larger councils' response rates were slightly higher than smaller councils' (Table 2). Along with these, the high response rate points to: (a) noticeable homogeneous interest on the topic among the Australian local councils and (b) reliability of the survey results.

The survey found that 13.6 percent of the responding councils are willing to adopt online planning at the *online decision support systems* level and 11.5 percent at the *online opinion surveys* level. Some 66.8 percent are considering having it at the *online discussion* level and providing strong two-way communication with their residents. Another significant result was that almost all councils now see the Internet as an inevitable technology for the *online service delivery* (Table 3).

Survey results indicate that ICT applications are now firmly embedded in most of the responding local planning authorities (Table 4). The growth of the Internet made it possible to obtain a wide range of services online. The use of the Internet and GIS is a recent development in the provision of planning services to the public. Many planning authorities have responded to the challenge by providing a range of sites orientated at various aspects of service delivery. In most of the Australian local councils, technical applications such as GIS and the Internet are now becoming well established; but in some of them, these applications are still being developed and enhanced. In some remote localities, however, the use of these technical applications is more varied and has the potential for further development.

One of the most striking features of the survey is the dramatic demand on the use of digital datasets and maps in planning departments. The survey pointed out that 89 percent of planning departments in LGAs are making use of digital datasets and maps. It also showed that with respect to GIS, 81.2 percent of responding councils have fully operational GIS. The survey found that 91.4 percent of planning departments of local councils—those with GIS—are utilizing GIS in their planning processes. Common planning-related application areas of GIS include: urban planning, planning inquiries, property services, various engineering applications, infrastructure planning, environmental planning, neighborhood planning, urban design, rural planning, and urban renewal.

One of the good indicators in determining the ICT level of a local council is its capability to produce in-house digital data for its planning process. About 80 percent (80.1) of local authorities have facilities to collect and manipulate data to use in planning operations. Besides that, 83 percent of local councils are using other governmental departments' electronic data and map sources and 32 percent of authorities are using electronic data from private companies.

With the rising issue of public participation, the importance of information distribution has come to the forefront, particularly at the local levels. As councils are realizing the benefits of replacing paper-intensive processes with direct access to information and timely feedback, information is being made available digitally that was previously difficult to locate or assimilate. As high as 73.8 percent of the councils provide and distribute planning information in digital format to the government, nongovernmental institutions, and the public.

With the increasing use of GIS technology in planning and with the growing importance of information distribution, the Web provides an ideal medium to make these previously advanced GIS tools accessible to a wider audience. The survey results confirm this statement, as 32 percent of local councils make planning information publicly available on their Web sites. Moreover, 12.1 percent of local councils make planning information available to the public via their Internet GIS sites.

On average, local councils have been using GIS for about six years. However, a comprehensive GIS was accommodated in most of the capital cities more than a decade ago (e.g., Canberra 20, Brisbane 17, Perth 10 years). In terms of dedicated GIS staff, there are 1.6 full-time and 1.4 part-time GIS specialists employed, although a relatively large number of planning staff uses GIS casually for their planning tasks (Table 5).

Four major GIS software packages are dominantly used for planning applications. These are: MapInfo (65.8 percent), ESRI (25.3 percent), Intergraph (5.4 percent), and Autodesk (5.4 percent). Besides these major GIS software packages, 22.9 percent of the councils are making use of either their in-house developed software or one of the popular Australian GIS software packages, such as AusSoft Latitude (Table 6). One of the interesting findings is that remote and small councils generally prefer to use state government's in-house developed/customized software packages or purchase light GIS packages that would meet their limited needs.

Expected results were observed from the analysis of the divide between LGAs in terms of population and council administra-

	Metropolitan city councils	Metropolitan town or shire councils	Regional city councils	Regional town or shire councils	All local councils
Years since GIS first established (years)	6.4	5.9	7.2	5.6	5.7
Full-time GIS staff (people)	2.9	1.6	2.1	0.8	1.6
Part-time GIS staff (people)	0.9	0.6	1.3	0.7	1.4

Table 5. Local councils' GIS personnel and years of GIS utilization

	Metropolitan city councils (%)	Metropolitan town or shire councils (%)	Regional city councils (%)	Regional town or shire councils (%)	All local councils (%)
MapInfo	50.7	47.2	56.3	79.8	65.8
ESRI	40.3	33.3	29.2	16.6	25.3
Intergraph	10.4	5.6	4.2	3.7	5.4
AutoDesk	3.0	5.6	10.4	4.9	5.4
Other	22.8	16.7	19.4	36.1	22.9

Table 6. Local councils' use of GIS software

	Metropolitan city councils (%)	Metropolitan town or shire councils (%)	Regional city councils (%)	Regional town or shire councils (%)	All local councils (%)
Considering GIS	85.7	50.0	80.0	42.1	49.3
Intention to use Internet for public participation in planning	68.9	64.3	51.0	39.4	49.3
Intention to use Internet for online planning	93.2	90.5	94.1	81.5	86.4

Table 7. Local councils' intention in ICT utilization

tion size and location. In general, LGAs population and local council's administration size—as well as the council's budget—is a more determinate factor on the divide than its location, metro or regional. This is likely occurring because metropolitan city councils are better equipped with ICTs than regional town or shire councils are. As these technologies are becoming more affordable and advanced, however, their utilization among the local councils is expanding rapidly. A large number of councils that are currently not utilizing ICTs are now seriously considering these technologies (Table 7). Among the councils with no operational GIS, almost half of them (49.3 percent) are considering establishing and benefiting from GIS in their planning tasks. In general, this consideration is stronger, particularly at larger councils.

Most c*ity, town, and shire administrators appear concerned about providing online services to citizens to encourage their participation in the planning process. A significant number of them are planning to provide information and planning services online.* Currently, 49.3 percent of responding councils intend to use the Internet as a tool for public participation—at different levels—for planning. When we looked at the metropolitan and regional divide in councils' intention to utilize ICTs, we observed that, in general, metropolitan councils have greater intentions to use ICTs as a public participation medium compared to regional councils. Additionally, city councils are more willing to apply ICTs for online planning than town and shire councils are. *Most city, town, and shire administrators are extremely interested in providing online planning, including online transactions to their residents.* Some 86.4 percent of the councils are interested in using the Internet for online planning within the next five years.

Respondents were asked to identify any obstacles that existed in adopting e-planning effectively within their organization. *Lo-*

	Metropolitan city councils (%)	Metropolitan town or shire councils (%)	Regional city councils (%)	Regional town or shire councils (%)	All local councils (%)
Budget	28.0	45.2	43.1	57.9	49.7
Technology	49.3	38.1	37.3	44.4	44.7
Technical staff	28.0	31.0	35.3	52.3	43.9
Lack of public interest	21.3	28.6	29.4	31.9	29.9
Accessibility	16.0	9.5	13.7	15.7	15.2
Privacy	13.3	19.0	17.6	12.0	14.2
Lack of planning system	10.7	14.3	19.6	12.0	11.2
Lack of vision	10.7	7.1	7.8	7.9	8.6
Legislation	10.7	7.1	9.8	6.9	8.3

Table 8. Obstacles in online planning implementation

	Metropolitan cities (%)	Metropolitan towns or shires (%)	Regional cities (%)	Regional towns or shires (%)	All localities (%)
High-level potential	71.6	71.4	45.1	31.3	45.2
Medium-level potential	23.0	23.8	45.1	33.6	32.1
Low-level potential	5.4	4.8	9.8	35.1	22.7

Table 9. LGAs potential for online planning

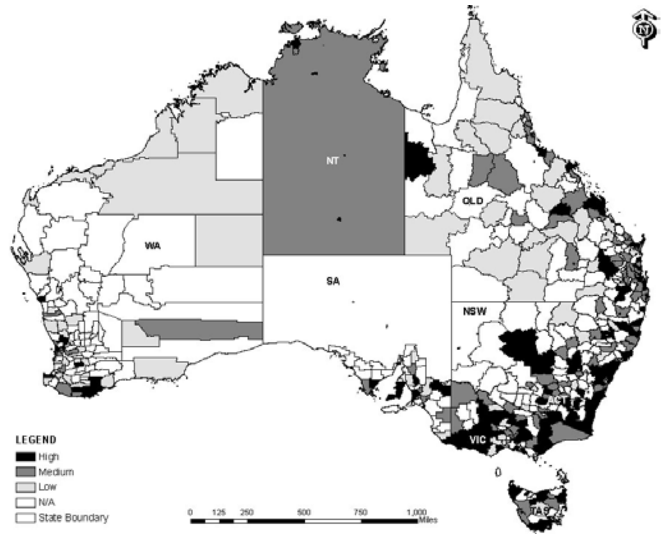

Figure 5. LGAs potential for online planning

cal governments with limited interest in providing online planning listed the lack of citizen demand and limited value to the community as their reasons. They also listed cost, security, and privacy issues. Only 18 respondents stated no obstacles existed. The remaining respondents identified a range of obstacles: budgetary limitations (49.7 percent), complexity of technology and automation of the process (44.7 percent), lack of experienced technical staff (43.9 percent), lack of interest among the public (29.9 percent), the digital divide and accessibility problems (15 percent), privacy and data-related problems (14.2 percent), lack of understanding the planning system (11.2 percent), lack of vision of the council's administration (8.6 percent), and restrictions of the planning legislations (8.3 percent) (Table 8).

Local Councils' and Residents' Potential for Online Planning

Evaluation of the potential of LGAs depends on many factors, including detailed surveys and feasibility analyses at the local level. This research, however, examined generic factors to obtain an overall idea on the potential of LGAs for online planning. To determine the level of potential, this research grouped LGAs in three categories: "high," "medium," and "low" levels of competence for online planning (Figure 5).

The LGAs that carry a "high" potential for online planning are the ones where household computer and the Internet access are equal to or more than 40 percent; the planning departments have an operational GIS system; and the councils are currently using the Internet as a medium for public participation in planning.

The LGAs with a "medium" level of potential are the ones where household computer and the Internet access are between 20 percent and 40 percent; the planning departments have either an operational GIS system or are considering GIS; and currently the councils are using or intend to use the Internet as a medium for public participation in planning.

The LGAs with a "low" level of potential are the ones where household computer and the Internet access are below 20 percent; the planning departments have either no operational GIS system or are not considering GIS; and currently the councils are not using or have no intention of using the Internet as a medium for public participation in planning.

The distribution of LGAs' potential clearly reveals that for online planning applications, disadvantaged councils and households are the ones in the remote regional areas. In contrast to that, most of the councils and their households in the metropolitan areas have a great potential to go online for planning (Table 9).

Research findings point out rural and remote LGAs as vulnerable localities in terms of technology adoption; however, access and equity issues are not only limited to rural and remote Australians. There are also a range of potentially disadvantaged groups—unemployed, low income, people with disabilities—in the metropolitan cities whose needs require consideration.

Local Councils' Experiences in Online Planning

Contrary to the short history of online planning, Australia has a large number of initiatives in this field. One of the good practices is Blue Mountains Council's Planning Initiative. The Internet has been used very effectively by the council to exhibit its local environmental plan. The council has taken great care to base its planning instruments on accurate data about the local environment (Herborn 2003). Residents are not only able to obtain detailed information on land use, infrastructure, vegetation, and other data within land parcels, but also communicate with council's planners online. By making this information publicly available, it also became open to challenge and updating (Blue Mountains City Council 2004). Herborn (2003 :12) says that:

In the last 10 years a very high proportion of councils have developed websites in Australia. Some provide maps that can be browsed and downloaded as a PDF file and some provide maps by using Internet GIS. What is currently available at the Blue Mountains City could become widespread in the future. Its website is distinguished by its greater depth and the degree of interactivity with its mapping system. It provides a model that could be imitated by other councils striving to encourage public participation in planning.

The Brisbane Smart City Initiative provides a good example for online planning. In this project, GIS and the Internet are used as platforms to form a two-way communication and a collective vision for the city that incorporates eight strategic direction statements: (1) a clean and green city, (2) an accessible city, (3) a city designed for subtropical living, (4) a smart and prosperous city, (5) a creative city, (6) an inclusive city, (7) an active and healthy city, and (8) a regional and world city (Brisbane City Council, 2005). This project also incorporates several other initiatives to support planning discussions, such as OurBrisbane, YourCityYourSay, and Queensland government's GetInvolved portals. These three portals are among the important elements of the Brisbane City Council's e-governance program. The Brisbane City Council also developed effective initiatives to narrow the digital divide. In addition to the provision of PCs in public libraries, the council's plan also entails making low-cost hardware available to individuals. One example is partnership with Green PCs—a social enterprise that intended to bridge the digital divide—in selling recycled computers that are refurbished to accommodate the Internet usage (Odendaal 2003, Infoxchange 2005).

Another example of good practice is the initiative implemented by the NSW state government. In NSW, planning information is being made available through the Web via a system called GIS-based Planning Information (iPlan). A substantial number of the LGAs in NSW have a variety of information online such as local environmental and town plans. It makes planning information more accessible and is a major step towards the democratization of information and GIS. The land-development and real estate industries derive benefits from the iPlan as well as do the local communities (Herborn 2003). Local communities need information about planning controls in neighboring LGAs. iPlan successfully provides improved access to that information with a two-way communication opportunity (NSW Government 2004). The iPlan's vision can be summarized briefly as: (a) one-stop shop for planning information and services from government and industry; (b) fast and efficient retrieval of planning policies and controls; (c) informed strategic planning through improved access to infrastructure, natural resources, zoning, land use, transportation, socioeconomic, and other relevant information; and (d) facilitation of public participation in planning the future of NSW (Department of Infrastructure, Planning and Natural Resources 2005).

Conclusions

Over the past two decades, the issue of public participation in planning was one of the central subjects of discussion in Australia (Troy 1999, Gleeson and Low 2000, Uddin 2004). With the tremendous pace of development in ICTs, and their increased use among the Australian local governments and the public, ICTs have become important tools to foster public participation in planning (Stein 1998, Singh 2002, Odendaal 2003, Local Government Managers Australia 2005).

As Herborn (2003) stated, prospects for online planning in Australian cities are bright. The thresholds for the use of online planning are becoming lower. This means that more people are potentially able to use online systems to enhance their access to planning information and to actively debate planning proposals.

A large number of councils in LGAs across Australia have the background and infrastructure to establish online planning. Furthermore, councils in more than three-quarters of those LGAs surveyed consider the Internet to be an extremely important source of planning information. A significant number of residents in Australia are able to use computers and the Internet, and their level of use varies significantly across LGAs. However, the prerequisites for the adoption and development of online planning are present in many councils.

Furthermore, there are a number of good initiatives on the development of online planning in Australia. They are using online planning instruments to widen and deepen public participation. Similar systems can be developed in other LGAs throughout Australia, and this would lead to a wider public participation and democratization of the planning process.

The digital divide problem urgently needs to be overcome and Australian governments and nongovernmental organizations (NGOs) are developing a wide range of initiatives to close the divide (Centre for International Research on Communication and Information Technologies 1997, 1999 Asia Pacific Economic Cooperation 2001, Infoxchange 2005). A good example would be the ACT state government's (2002) Community IT Access Plan. This plan include initiatives to: (a) provide public ICT access through libraries and community centers; (b) offer ICT training programs; (c) provide ICT access and training to disadvantaged target groups, including people with disabilities and their careers; (d) distribute free computer training resources through libraries, shopfronts, and community centers; and (e) establish a PC Reuse Scheme to provide affordable refurbished computers to people on low incomes and not-for-profit community groups. The continuum of these policies will help in narrowing the divide and increase the accessibility of online planning.

Hewitt (2000) and Warschauer (2003) emphasized online planning as an exciting frontier, but technology alone is not going to get us there. What it is going to take us there is using technology as a tool to provide greater accountability, transparency, and collective decision making through better and more meaningful public access to government information. Therefore, online planning activities should not be focused solely on technology but be supported by it, and e-participation should supplement, not substitute for, traditional modes of public participation. More important, prime attention needs to be on the development of policies and initiatives for social inclusion. As the Department of Communications, Information Technology, and the Arts (2005) states, we also need to keep in mind that using technology to promote social inclusion is a productive approach in ensuring digital inclusion.

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Comparing GPS Receivers: A Field Study

Kindra Serr, Thomas Windholz, and Keith Weber

Abstract: *This paper compares the precision and accuracy of five current global positioning system (GPS) receivers—Trimble ProXR, Trimble GeoXT without WAAS, Trimble GeoXT with WAAS, Trimble GeoExplorer II, and an HP/Pharos receiver. Each of these receivers, along with other similar units, are frequently used today for data collection and integration within a geographic information system (GIS). To compare receivers, we conducted a field study of 15 established survey markers in the city of Pocatello, Idaho. The points were observed on ten different dates with equivalent settings (e.g., averaging and acceptable point dilution of precision—PDOP) and were differentially corrected using Idaho State University's Community Base Station. Overall, the results indicate that the GeoXT is well suited where submeter accuracy is required, while the Pharos receiver is a viable alternative for applications with accuracy requirements of +/- 10 meters and more.*

Introduction

The use of GPS receivers has become widespread over recent years. Many applications, from hunting to surveying, benefit greatly from these devices. The level of accuracy required from application to application varies greatly. It is important to recognize the grades of GPS receivers, namely consumer, mapping, and survey grade, and their ability to accurately map features with or without differential correction. The accuracies of these receivers range from centimeter to several meters, making it necessary to evaluate how accuracy and precision can affect individual applications.

When using a GPS receiver to collect field data, accuracy can be very important, especially when collecting data for use with high-spatial resolution imagery. Quickbird multispectral imagery, for example, achieves a resolution of 2.4 meters per pixel. To coregister corresponding ground sample locations within the correct pixel(s), an accurate GPS receiver is required. To ensure that each field observation is coregistered with the correct pixel, a GPS receiver must achieve an accuracy < 50 percent of the pixel size (e.g., +/- 1.2 m @ 95 percent CI where Quickbird imagery will be used). The increased availability of less expensive, consumer-grade GPS receivers, such as the HP/Pharos receiver used in this study, that are compatible with common GPS software, such as ESRI's ArcPad or Trimble's TerraSync, has raised concern about data quality. Many such receivers collect data that cannot be differentially corrected, increasing the margin of positional errors in the data collected. Consumer-grade receivers are also unable to control the quality of PDOP during data collection, further increasing positional error. To assess the validity of these concerns a field study was designed to calculate and compare the accuracy and precision of several GPS receivers. The goal of this study was to identify the receivers most appropriate for various research, remote sensing, and GIS applications.

Similar studies have been conducted in which GPS receiver accuracy has been investigated. Some studies compared receivers under various collection protocols. Studies conducted in Ridley State Park in Pennsylvania (McCullough 2002) and the Clackamas Test Network in Oregon (Chamberlain 2002) tested the capability of the Trimble GeoXT receiver in forested and clear areas with similar procedures and yielding comparable results in each study. Using internal and external receivers (antenna located within the receiver—internal, antenna attached externally to receiver—external), the studies experimented with WAAS and postprocess differential correction techniques, but used higher PDOP masks (e.g., PDOP mask = 7.0) than used in this study (PDOP mask = 5.0). Published studies comparing various GPS receivers are limited. One study completed in the summer of 2000 compared the accuracy of five different GPS receivers under forest canopy cover with Selective Availability (SA) off (Karsky et al. 2000). In this study, WAAS was not used because it was not yet available. Differential correction was performed on files that could be corrected and positions were taken at known points in forested areas with 1, 60, and 120 positions averaged for each point. None of the above studies mentions how often points were collected over time or how many times points were collected. Each study concluded the receiver tested was appropriate for its research purposes, whatever those may have been. Overall, previous studies have taken into account some of the aspects related to GPS receiver accuracy, but a comprehensive analysis was not completed.

A study conducted in McDonald Forest, located in western Oregon, investigated the accuracy and reliability of consumer-grade GPS receivers under differing canopy conditions. Six different GPS receivers were evaluated for accuracy under three different canopies: open sky, young forest, and closed canopy. Although the collected data was unable to be differentially corrected, points were averaged and compared relative to the known location, allowing for the receivers' accuracies to be compared to one another (Wing et al. 2005). This evaluation did not include real-time correction, nor was it conducted over an extended period of time.

In this paper we describe a field study comparing different GPS receivers to determine optimum applicability for various uses.

$$1.96 \cdot \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n-1}} \qquad 1.96 \cdot \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2}{n-1}}$$

Equation 1. Accepted true location based on the mean of observations per sampling site.

$$1.96 \cdot \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \mu_x\right)^2}{n}} \qquad 1.96 \cdot \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - \mu_y\right)^2}{n}}$$

Equation 2. Precision of observations at 95 percent confidence.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

Equation 3. While the accepted "true" location was based on independent, survey-grade GPS observations of control points, accuracy of tested GPS receivers was calculated as given above at 95.

	Precision		Precision Sum of Squares	Accuracy		Accuracy Sum of Squares
	x	y		x	y	
ProXR	0.38	0.46	0.59	0.46	0.78	0.91
GeoXT	0.43	0.59	0.73	0.53	0.77	0.93
GeoXT with WAAS	0.36	0.66	0.75	0.43	0.96	1.05
GeoExplorer II	1.96	2.90	3.50	2.02	3.25	3.83
Pharos	1.68	2.32	2.86	3.73	4.21	5.62

Table 1. Results of GPS receiver precision and accuracy (in meters) at 95 percent confidence

	Limit	Counts	Limit	Counts
ProXR	>0.5	14%	>1	0%
GeoXT	>0.5	16%	>1	1%
GeoXT with WAAS	>0.5	20%	>1	3%
GeoExplorer II	>0.5	68%	>1	37%
Pharos	>0.5	78%	>1	67%

Table 2. Proportion of extreme positional outliers (>0.5 and >1.0m thresholds) by receiver [0]

Methods

The study area was located in the city of Pocatello and environs (Figure 1). Fifteen points were selected from known locations in Pocatello, Idaho. These points were obtained from the Pocatello ground-control database. Each was referenced in the field with permanent survey markers so the exact location could be relocated easily. Each point was visited ten times over a period of one month at approximately the same time each day (+/- 1 hour). The points were selected for their accessibility and visibility to GPS satellite signals (avoiding vegetation or building interference). These criteria were followed to provide uniformity and the best operating condition for each GPS receiver, thus verifying the precision and accuracy reported by the manufacturer and eliminating as much environmental influence as is possible in a field-based study. Data collection occurred on days where PDOP was within acceptable limits (< 5.0). This was determined using Trimble's QuickPlan software.

The location for each point was observed with the following GPS receivers:

1. Trimble GeoXT receiver with WAAS
2. Trimble GeoXT receiver without WAAS
3. Trimble GeoExplorer II
4. Trimble ProXR
5. HP iPaq with Pharos Navigation software and antenna

Points were collected in latitude/longitude (WGS84), the native reference system for GPS receivers. This was done to avoid any transformation errors that may occur during projection. Receivers did not collect data when the PDOP was > 5.0 to reduce this type of error. Receivers averaged 120 positions per point each time a site was visited. The weather conditions on most collection dates were comparable and skies were relatively cloudfree in all cases.

After collection, each point file was differentially corrected using files from Idaho State University (ISU) GIS Training and Research Center's (GIS TReC) GPS Community Base Station, with the exception of those points collected with the HP/Pharos receiver (the Pharos receiver does not collect the necessary information for differential correction through a base station). The base station was located on the ISU campus in Pocatello. The location of each point ranged from 1.5 km to 12.6 km from the base station. Seven of the 15 original points were then revisited and their location collected using a Leica GPS 530 survey-grade GPS receiver (+/- 0.1m @ 95 percent CI) (Leica 2002), corrected in real time using the ISU College of Technology's GPS CORS station (NGS 2005), also located on the ISU campus. These seven locations were used to assess the accuracy of the GPS receivers, while all 15 locations were used to assess precision.

In this study, precision refers to the repeatability of a specific GPS receiver collecting locational estimates. The error value (i.e., precision) was based on a relative comparison among measurements (Equations 1 and 2) of the same unit on different days. Accuracy, however, is not a relative comparison, but an absolute comparison. In this case, the error value (i.e., accuracy) was calculated (Equation 3) by comparing measurements of a single unit on different days to the known true location of the observed point. These points were collected independently (i.e., different observer, different base station, and well-established GPS receiver accuracy) and corrected using the nearby (< 12 km) CORS station in real time. Thus, 150 samples were collected to calculate precision (15 points visited 10 times each) and 70 samples were collected to calculate accuracy (7 points visited 10 times each).

Spatial analysis of these points was conducted within the native WGS84 geographic reference system. Conversion from

	Stated Accuracy (m)	Calculated Accuracy (m)	Cost
ProXR (Trimble 2005a)	0.5	± 0.91	$8,490 (including data logger)
GeoXT (Trimble 2005b)	<1.0	± 0.93	$4,295
GeoExplorer II (Trimble 2005c)	2.0-5.0	± 3.83	$3,995
Pharos iGPS 360 (Pharos 2005)	<10.0	± 5.60	$300

Table 3. Correlation between manufacturer stated accuracy measured accuracy, and cost of receiver

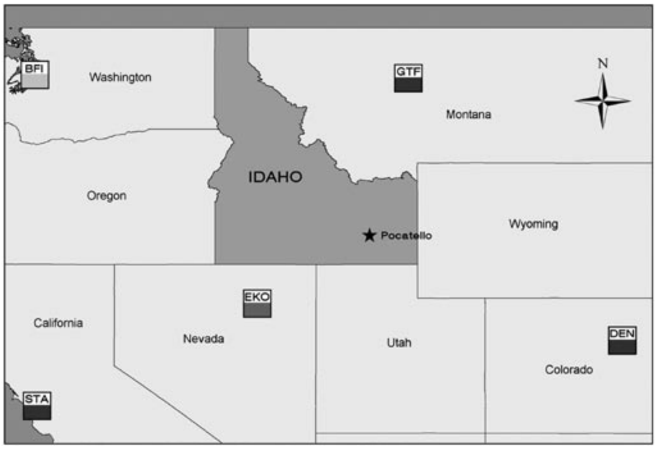

Figure 1. The location of the Pocatello study area and WAAS stations

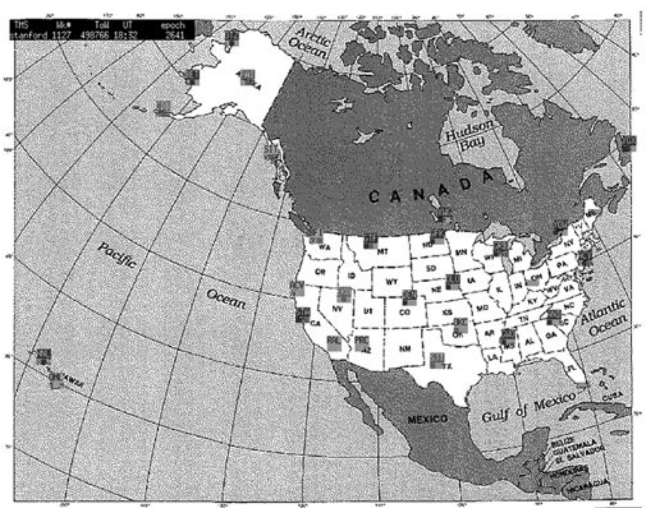

Figure 2. The location of WAAS stations across the United States. Blue indicates active, gold indicates passive, and red indicates communication failure.

decimal degrees (WGS84) to meters was performed using ESRI's ArcGIS software. Resulting units are reported in meters.

Results

The results of precision and accuracy calculations for the tested GPS receivers are given in Table 1. There is a slight difference in the magnitude of errors between x and y coordinates. Sum of squares was used to assess positional accuracy (i.e.,). To assess the utility of each receiver for various applications we used sum of squares.

	Precision	Accuracy	Applicable image resolution	Effective Map Scale
ProXR	±0.59	±0.91	>1.8m	1:1,075
GeoXT	±0.73	±0.93	>1.9m	1:1,100
GeoExplorer II	±3.50	±3.83	>7.7m	1:4,524
Pharos	±2.86	±5.62	>11.2m	1:6,639

Table 4. Suitability of various GPS receivers for use with remote sensing imagery and GIS mapping products

Extreme values of individual point observations (100 percent CI) varied between individual receivers (Table 2). The largest error observed was recorded with the HP/Pharos unit (8.41m).

Discussion

The calculated accuracies were all within manufacturer specified ranges. Table 3 lists manufacturer-stated accuracies with accuracies reported in the results of this paper. Also given is the cost of each receiver provided by the manufacturer. Selecting a GPS receiver that has acceptable accuracy and a reasonable price is important. Generally, increased accuracy comes at higher expense as demonstrated by this study. While purchasing a low-cost receiver, such as the Pharos iGPS 360, may create less expense for an organization, accuracy is compromised. The best accuracy was achieved using the Trimble ProXR (+/- 0.5 m @ 95 percent CI), but this accuracy comes with increased expense. Based on this information, we conclude that accuracy and cost are directly linked. Higher accuracy results in higher receiver costs.

In Table 1, we reported diminished accuracy when the wide area augmentation system (WAAS) was activated on the Trimble GeoXT receiver. We speculate that the cause for this performance decline was the lack of station coverage within our study area. WAAS uses approximately 25 ground reference stations that collect correction data for effects of the atmosphere, clock errors, and slight satellite orbit errors (ephemeris) (Figure 2). The closest ground station to our study area was the Elko, Nevada, station, which is approximately 360 kilometers away (Figure 1). However, the Elko station was offline at the time of this study, making the Great Falls, Montana, station the closest active reference station (523 kilometers away). We assumed that the correction factor applied for the column of atmosphere near Great Falls departed from conditions in and around the study area, therefore, making the WAAS correction less reliable for our application. This was not anticipated, nor is it expected for all applications.

In general, outliers, or extreme values, were within vendor-specified ranges. The Pharos receiver had the greatest extreme values. Thus, where accuracy and precision are concerned, the more expensive receivers outperformed less expensive receivers. It should be noted that Pharos GPS receivers cannot mask for PDOP and do not collect files suitable for differential correction. As indicated in Table 1, the lack of the ability to differentially correct the data is reflected in the relatively large decrease in accuracy compared to its precision. The results reported for the Pharos receiver were effectively best-case scenarios, inferring that accuracy and reliability will quickly deteriorate under more realistic conditions (i.e., poor PDOP, obstruction, etc.).

The achieved accuracy and precision may be attributed—at least in part—to precollection planning. To better ensure field conditions would satisfy the PDOP mask, Trimble's QuickPlan software was used to determine the optimum collection window. This procedure virtually guaranteed that the Pharos receiver, as well as the other receivers tested, would also collect data under ideal conditions. The use of receivers with the ability to implement a PDOP mask allowed us to monitor PDOP, thus assuring the Pharos receiver was collecting data within the same specified PDOP parameters. A more realistic scenario, however, often requires the user to collect data completely independent of other receivers and planning software/tools. For example, if the only available receiver was a Pharos, PDOP could not be observed or masked, which would lead to reduced accuracy. For these reasons, the Pharos receiver cannot be recommended for any tasks requiring < 10 m accuracy, yet it is definitely a viable alternative for other applications, such as data collection for lower resolution imagery (i.e., Landsat).

A limitation of this study was that accuracy calculations were not based on continuously observed data, but rather on field sampling and revisiting a site over a period of time (i.e., one month). This study does, however, offer a comparison between various GPS receivers under similar research conditions. The same level of accuracy detailed in this study may or may not be achieved using similar equipment. These accuracies were based on methods specifically set up to evaluate the equipment available (i.e., long observation times) and may not be similar to typical operating conditions.

Reliable accuracy and precision of GPS receivers has become increasingly important concomitant with advances in high-spatial resolution imagery. GPS receivers with accuracies of 2 to 5 meters, such as the Trimble GeoExplorer II, are unable to collect data that will reliably coregister within the correct 2.4-meter pixel of Quickbird imagery (Table 4) or other similar imagery. Depending on these types of project-dependent considerations, it may be necessary to use a GPS receiver capable of achieving superior accuracy and precision. The Trimble GeoXT tested in this study is a viable receiver for applications requiring high accuracy. Although the Trimble ProXR achieved better results, the GeoXT offers a user-friendly interface and compatibility with common GPS software, such as ESRI's ArcPad or Trimble TerraSync, effectively lowering the total cost of ownership by decreasing the time it would take to learn to use the receiver.

Conclusions

This study assessed four GPS receivers and determined both precision and accuracy at 95 percent confidence. While selection of the optimal GPS receiver is a project-dependent consideration, the data we present is important for GIS managers to help them: (1) understand the differences in horizontal positional accuracy obtained from various GPS receiver types; (2) ensure coregistration of GPS-acquired features and satellite or aerial imagery; and (3) determine the appropriate GPS receiver to use to satisfy mapping scale requirements.

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A User-Centered Model for Community-based Web-GIS

Nicholas Rattray

Abstract: *Like their counterparts in the private and public sectors, community-based organizations are increasingly implementing Web-based geographic information systems (WGIS). Such projects often face a special set of challenges: insufficient financial resources, a set of users with limited technical expertise, and the constant threat of obsolescence. There is a lack of documented research on how grassroots groups and nonexpert users are making use of WGIS. Without more evidence, it is difficult to evaluate whether or not these advances in technology will actually lead to the improvements suggested by their proponents: increased public participation, transparency in government, geographic literacy, and better data-driven decision making by community-based organizations (CBOs). Examining a case study in California, I show that a customized, distributed Web services model is capable of capitalizing on economies of scale and remote technology while maintaining its commitment to serving nonexpert GIS users. Analysis of users from the Neighborhood Knowledge California (NKCA, http://nkca.ucla.edu) system demonstrates that WGIS projects enable anonymous users to upload and integrate local data, facilitate interagency cooperation, and more efficiently utilize publicly available geospatial and demographic data.*

DEMOCRATIZING GIS

The increasing availability of geospatial data on the Internet has led some commentators to declare that "[c]artography has gone from spectator sport to participatory democracy" (Kelly 2005). According to *The New York Times,* the introduction of the open-source application from Google Maps signals the arrival of Internet-based geographic information into the broader public imagination (Darlin 2005) and the advent of "do-it-yourself cartography" (O'Connell 2005). Indeed, this trend is also exemplified by the widespread popularity of Web sites that offer driving directions and quick access to spatial information about local businesses. Both innovative amateur Google Maps developers and the more passive consumers of mapping Web sites find increased opportunity to make use of geospatial data that was previously difficult and expensive to access. But do these trends herald cartographic democracy, or are they better characterized as effects of private market innovation? The implicit message from proponents of "do-it-yourself" cartography is that anyone can use and consume digital geospatial data, and because it is on the Internet, it is accessible to all; in other words, "If you build it, they will come." While this approach may be appropriate for amateur Web developers or corporations with large budgets, community-based GIS projects face a more stringent set of requirements.

The demystification of cartography has accelerated in the past two decades. Since the mid-1990s in particular, GIS has become more accessible to those individuals not trained as GIS professionals. These nonexpert users—by this I mean people with little computer experience, occasional users, GIS novices, and the interested public—are increasingly able to take advantage of mapping software. Friendlier user interfaces, substantial increases in publicly available data, public investment in training and education, and other factors contribute to wider usage of GIS by nonexperts.

Several questions arise on how Web-based technologies can help to meet goals of public participation GIS (PPGIS). Web-based GIS (WGIS) refers to geographic information systems that utilize the Internet to host distributed applications that can be shared and made publicly accessible. Examples of WGIS include mapping applications that aid users in obtaining driving directions as well as property information systems for municipalities. Many of these systems significantly improve the ability of the public to begin using computer mapping. While it has the potential to lead to greater participation (Aitken 2002), WGIS also creates a number of new barriers that are more formidable than they first appear. For example, the range of specialized skills and knowledge required (Traynor and Williams 1997) or the way in which GIS software can be empowering or disempowering (Elwood 2002) may be exacerbated in WGIS. There have been few theoretical treatments of WGIS, and an even smaller number of studies examining how Internet-based GIS can be used as part of PPGIS projects (Kingsley 1999; Wong and Chua 2001, 2004; Casey and Pederson 2002). However, there is a lack of documented research on how grassroots groups and nonexpert users are using WGIS. Lacking empirical evidence, it is difficult to evaluate whether or not these advances in technology will actually lead to the improvements suggested by their proponents: increased public participation, transparency in government, geographic literacy, and better data-driven decision making by community-based organizations (CBOs).

In this paper, I critically examine a case study of community-based WGIS from California, Neighborhood Knowledge California (NKCA, http://nkca.ucla.edu). NKCA and its sister projects at the University of California, Los Angeles (UCLA) have been discussed as grassroots mapping projects that exploit the "utopian potential of GIS" (Warren 2004). Community-based WGIS has the potential to meet the impressive expectations that technological advances enable, but only with careful planning and development, attention to the end-user, and cooperation between agencies and other similar projects. I argue that system architecture, user interfaces, and the development of data partnerships are key components in building sustainable, effective WGIS projects. The case studies demonstrate that a customized, distributed Web services model is capable of capitalizing on economies of scale and remote technology while maintaining its commitment to serving nonexpert GIS users. Analysis of users of the NKCA system illustrates how WGIS projects enable anonymous users to upload and integrate local data, facilitate interagency cooperation, and efficiently utilize the range of publicly available data.

The purpose of this article is to inductively develop lessons from a community-based GIS project in California to ascertain the key mechanisms for realizing the potential of WGIS while addressing its principal challenges. In this case, three of the challenges were: (1) changing software, hardware, and geospatial data, (2) a diverse range of users, and (3) financial sustainability. The challenges were addressed by utilizing a distributed Web services application model, emphasizing the importance of the user interface, and cultivating long-term community partnerships aimed at leveraging limited financial and human resources. In addition, I explore the unintended consequences of the adoption of the WGIS model for community-based GIS. The NKCA project demonstrated that community users discovered novel ways to meet their research needs, often in a manner unanticipated by the developers. Finally, the efficacy of the project was due in part to its insistence on putting people before the technology. This deliberate, sustained approach to community-based WGIS offers more hope for cartographic democracy than does the more recent trends toward open-source geospatial applications of the Google Maps.

THE EMERGENCE OF COMMUNITY-BASED WGIS

In the 1990s, critics painted a fairly ominous picture of GIS based on what they considered to be its inherent limitations, its positivist epistemology, and the need for wholesale critical reconsideration (Lake 1993, Pickles 1995). Following a set of workshops and journal issues dedicated to GIS's underlying epistemological questions, the politics of information, and questions about access and application, a new set of research topics emerged (Obermeyer 1998; Craig, Harris, and Weiner 2002). This group of research has been labeled as "critical" GIS or "GIS and society" debates. Central to these debates are the observations that GIS is not value-neutral, often does not meet the needs of marginalized populations, and has a significant set of limitations. Contrary to the claims of its proponents, it is often unable to model on-the-ground processes. Even when GIS is able to capture local dynamics, the geospatial language that nonexpert mappers employ may not match terminology in the system (Rundstrom 1995, Fonseca and Egenhoffer 1999).

Research focused on participatory GIS builds on previous work in critical GIS in the past decade and most recently on approaches known as public participation GIS or PPGIS, a term derived from the field of urban planning (Obermeyer 1998). Urban planners tout the potential of GIS to aid in equity planning while simultaneously improving transparency in the planning process through bottom-up GIS (Talen 1998, 2000). Warren situates PPGIS projects in the domain of utopian projects where "technology is both the problem and, when inserted into more emancipatory social settings, the potential cure" (2004). In an attempt to move beyond the critical GIS debates of the 1990s, Warren contends that because the limitations of GIS have been exposed and contested, it retains the potential to democratize knowledge and serve as a technique for social activism.

Critiques of GIS have entered a "third wave" that "represents a more nuanced analysis of power" (Schuurman 2000). While the first wave of GIS critiques was often inflammatory and polemical, the second wave was marked by increased cooperation and progress. The third wave signifies the acknowledgment that while the epistemological issues inherent in GIS are no less important, they have been exposed and analyzed. Moreover, the limitations of GIS do not prevent its use for political resistance (Stonich 2002), and in some cases participation in project development can lead to "empowerment" (Parker and Pascual 2002). Despite working on widely varying issues, in different cities, and under substantially different contexts, most groups working on PPGIS projects share similar goals and challenges. Public sector actors often are concerned with transparency in decision making, greater public participation, and efficiency. Influenced by decreased public funding, community service mandates, and service-learning initiatives, university researchers attempt to make their research more accessible and relevant to the community in which they are situated (Esnard, Geleboter, and Morales 2001).

By the late 1990s, many groups active with community-based GIS moved their systems from either desktops or intranets to Web-based applications, leading to an entirely new set of challenges. Because the integrative and communicative features inherent in GIS design lent themselves to Internet technology, the move toward WGIS was probably inevitable and is likely to continue (Goodchild 2000a). Peng and Tsou (2003) contend that Web-based GIS increases the availability of geospatial data, improves dissemination of GIS analysis, and reduces end-user cost through the use of Web clients. Community-based WGIS also offers flexibility for the developers; a Web-based strategy enables customized user experiences and the opportunity to integrate locally produced datasets.

As Wong and Chua assert, however, "Web technology alone is not sufficient to enhance the capability of every community group and resident to use GIS, to change the reality that GIS is a specialized skill, or to significantly level the unequal socio-economic or political relationships that hinder participation in distressed communities" (2001, 2004). To realize the potential benefits, WGIS requires considerable investment and expertise, and its potential has only been realized in a few select cases. Hearkening back to the initial criticisms from human geographers, ineffective or faulty Web-based GIS can actually detract from public participation and community development efforts by discouraging users and heightening the divide between GIS professionals and nonexperts.

WGIS is subject to nearly all the same critiques leveled at GIS in the 1990s (Ramasubramanian 2004). Local production of data remains important (Talen 1998, Aitken 2002, Elwood 2002, Warren 2004), and the success and sustainability of information technology projects often depend on social and institutional factors beyond community control (Elwood and Ghose 2001). For example, data acquisition frequently involves a complicated set of interpersonal contingencies and power relationships rather than clear-cut economic transactions. Community-based GIS is developed with several sets of individuals, including clients (e.g., residents, CBOs, agency staff, politicians, researchers), software developers (e.g., university researchers, agency staff, consultants, etc.), project staff (e.g., community organizers, researchers, GIS experts, computer system administrators), and funders (municipalities, universities, foundations, the federal government). Responsibility for development, maintenance, usage, and financial solvency is dispersed through this network of overlapping actors. WGIS projects add complexity to traditional community-based GIS by increasing development costs, widening the client base, and heightening public visibility. Indeed, many projects have struggled to fulfill their difficult mandates in the face of a dizzying set of institutional relationships. Finally, PPGIS Web sites face competition from other online information resources. Moving the user experience from the desktop to the Web browser instantly creates the enticement of other content on the Internet. The "stickiness"—how long a user will remain on a single Web page—has become increasingly important (Burton and Walther 2001).

Wong and Chua discuss how the Internet offers both opportunities and barriers for PPGIS projects (2001 2004). WGIS offers four types of opportunities: lower cost, data transfer, interactivity, and connectivity. In general, lower costs are derived from increased economies of scale and the ease at which data can be disseminated to those with access to Web browsers. However, WGIS delivers data to anonymous users with a variety of characteristics often considerably more diverse than desktop- or intranet-oriented applications. This creates barriers based on the cost of interactivity, user diversity, copyright costs, and trust and legitimacy (Wong and Chua 2001, 2004). In addition to the increased initial investment in hardware and software development, the cost of interactivity is exacerbated by potential legal liability and decreased control of usage (i.e., copyright issues).

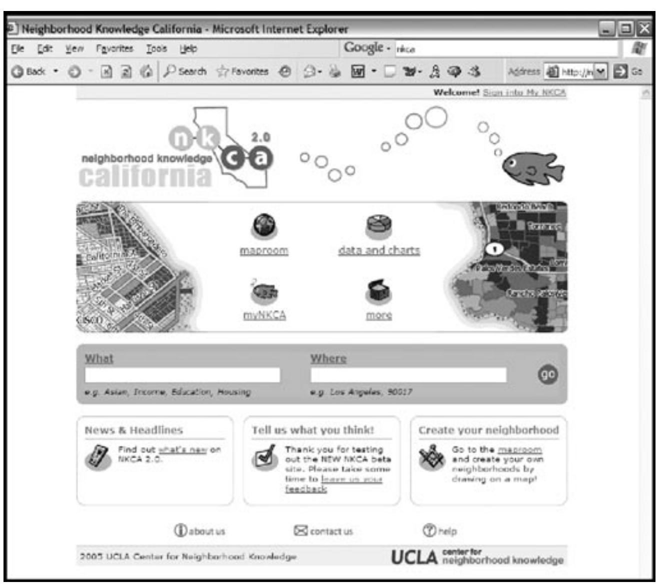

Figure 1. Home page of Neighborhood Knowledge California

The following case study illustrates how these opportunities and barriers have affected a community-based WGIS project in California. By pinpointing the lessons learned in extending PPGIS projects through utilizing Web-based technology, I show that the barriers presented by WGIS can be mitigated by means of developing customized applications that meet the needs of diverse users, conducting extensive and deliberate outreach, and building on existing networks of partners. Moreover, the three key components section that follows highlights the unique structures and institutional practices that emerged from several years of software development, outreach, and applied research.

Methodology

The argument presented in this paper represents an inductive analysis of three types of data based on my employment at the UCLA Advanced Policy Institute (API) from 2000 to 2003.[1] First, quantitative and qualitative data from user surveys provided information on the usage and demographics of project participants. In addition, I was a participant-observer; my experience as a GIS Web developer and technical assistance provider offered firsthand understanding of the day-to-day activities of both users and staff. Finally, published evaluation reports and articles of the API projects provided a historical context (Krouk, Pitkin, and Richman 2000; NKLA 2000; Richman and Kawano 2000; Modarres 2001; Pitkin and Rattray 2002; Steins 2003).

Background

Neighborhood Knowledge California represents one stage in the evolution of several related projects. The Center for Neighborhood Knowledge (CNK, formerly known as the Advanced Policy Institute) has been working on similar community-based WGIS projects since 1996. CNK is an applied research institute affiliated with the School of Public Affairs at the University of California, Los Angeles. Similar to research institutes at other large urban universities, CNK operates in several interrelated university-community partnerships, arrangements that are often fertile ground for successful community mapping projects (Esnard, Geleboter, and Morales 2001).

The first major project completed by the institute was Neighborhood Knowledge Los Angeles (NKLA, http://nkla.ucla.edu). NKLA presents housing and property data in a bilingual (English-Spanish), user-friendly format delivered through online maps and tables (Figure 1). Aimed at improving housing conditions for the city of Los Angeles, it is notable for the way it incorporated Web-based GIS analysis with a wide range of publicly accessible information. The longer-term goal of NKLA was to assist in monitoring residential housing conditions by providing an "early warning system" of housing disinvestment (Krouk, Pitkin, and Richman 2000; Richman and Kawano 2000). The project also deliberately promoted the democratization of public information, signified by its motto: "Neighborhood Knowledge is not just for the experts." Indeed, according to survey data of registered users shown, it was used in almost equal proportions by city staff, residents, community organizers, CBOs, and researchers. Nearly half of the users identify themselves as nonprofit employees, tenants, or community residents (i.e., nonexpert users). An independent evaluation of the project indicates that of the 5,200 registered users, 10 percent visited more than five times (Modarres 2001).

Despite the project's initial success, both project staff and Web site users identified areas that could be improved. Staff realized that NKLA´s maps of housing disinvestment tended to reinforce negative assumptions about housing conditions in Los Angeles neighborhoods. At the same time, several community groups began to seek alternative methods for utilizing NKLA´s geographic information and suggested customized tools tailored to their organizational objectives. Building on the "asset mapping" model popularizing by Kretzmann and McKnight (1993), NKLA staff produced a new spin-off program called "Interactive Mapping in Los Angeles" or "IAMLA," aimed at highlighting the wealth of social and cultural assets in several neighborhoods. The project resulted in Web-based maps of three low-income neighborhoods in Los Angeles with digital photos and bilingual descriptions created and uploaded by the high school students (Pitkin and Rattray 2002). Although these local projects were individually successful, they required additional funding and a significant investment in conceptual training and Web site development.

From 2000 to 2003, several related projects spun off from NKLA. Although each used the same basic technical platform, focused on addressing issues related to the digital divide (NTIA 1999), and offered user-friendly mapping tools for community research, they each had different funding strategies, clientele, user interfaces, and programmatic staff.[2] The Living Independently in Los Angeles (LILA) project launched in 2000 as "a consumer-directed and regionally focused online project to benefit people with disabilities living in Los Angeles County." Mirroring the model established by IAMLA, it utilized the labor of community researchers (most of whom were people with disabilities) to collect information. The technical and sociopolitical lessons of the collective experiences set the stage for NKCA (NKLA 2000).

While LILA and IAMLA demonstrated that uploading user "assets" enhances the "PP" in GIS projects, NKLA's integration of relevant administrative datasets, accessible maps, and bilingual interface exhibited the utility of WGIS. However, each of these projects targeted specific user groups, faced technological challenges, and in some respects lacked scalability. NKCA was developed as a new platform that incorporated the features of the prior projects, added new datasets, two novel applications, and extended the coverage of the maps to the state of California. NKCA also took advantage of an established set of community partnerships, a highly trained staff, and a loyal base of Web site users. At present, NKCA focuses on assisting community groups working in the area of affordable housing and community reinvestment. In addition to general demographic and economic information, NKCA features data relevant to researchers working on fair-lending and fair-housing issues.

For comparative purposes, we can look at statistics from the three-month period, May to July 2005.[3] NKCA received just over 4,000 visitors over this period at an average of 131 per day. Thirty-two percent of these users were "repeat visitors," a figure valued by the staff. The site generated an average of 16,241 hits per day (although this can be a misleading statistic), a measure that has shown a steady but gradual increase over the past four years.

Key Components in Community-Based WGIS

Three aspects of community-based WGIS projects are vital to their eventual success: building effective partnerships, emphasizing accessibility in the user interface, and developing flexible system architecture. While these aspects were important in community-based GIS prior to the move toward the Web-based strategies, they now have increased significance.

The common denominator in the CNK projects is the emphasis on the user. Although many WGIS projects prioritize technology and often lose sight of the human user, CNK maintained the mantra of placing people first. As shown in the following section, this philosophy pervaded each aspect of the project.

Durable Community Partnerships

The most important factor in these projects is the development of community partnerships. Various types of partnerships aim at achieving different goals, each playing a key role in "data intermediation" (Wong and Chua 2001, 2004). Funding partnerships ensure the financial solvency of the project. Partnerships with local governments encourage the use of Web-based software in the delivery of public services (e.g., NKLA). Publicly accessible data assists municipal staff by both helping them with their own tasks and helping them meet their obligations to disseminate information to city residents. Making data accessible differs from mere availability because the public can actually acquire and use it. Personal relationships, carefully nurtured over time, can be important factors in the success of maintaining such partnerships. Each of these partnerships provides clientele and reciprocal benefits, leading to increased stability.

One distinctive feature of the CNK model was the makeup of the staff. Most of the staff had experience in the discipline of urban planning, and more than 90 percent of the permanent staff members (as opposed to the students or the part-time staff) also had experience and interest in the subfield of community development. The staff was highly involved in strategic planning and organizational development and had worked in community organizing in some capacity. Thus, the cultural divide (Haklay and Tobón 2003, Urban-Institute 2005) that often exists between

GIS experts and community-oriented staff was absent.

Moreover, most of the staff had achieved competency in four key areas, and in a fairly consistent sequence. They were first involved in community development, followed by training as urban planning academics. Next, they become proficient in GIS, and finally achieved some level of competence with dynamic software programming and database manipulation. A few of the staff members lacked experience or proficiencies in some of these areas, but for the most part it was a staff with high technical competence in Web development and GIS, significant community experience, and solid academic credentials. Most important, they were urban planners first and computer scientists second. Like early pioneers of GIS (McHaffie 2000), they were unsatisfied with the existing technology and were ideologically committed to its modification, eventually developing a community-based WGIS.

One of the most exciting and unpredictable results of the NKCA project has been the range of applications it has been used for. Because it offered no-cost tools on the Web, it was impossible to predict how actual usage would occur. Three types of cases show how it has been used: a legal services organization from the San Francisco Bay Area, a coalition of CBOs in San Diego, and a local city planner from San Luis Obispo.

1. The multiplier affect: The NKCA staff certainly could not have predicted that another nonprofit support organization would create their own tutorials specifically aimed at their clients in need of demographic information. Legal Services of Northern California attended one of the NKCA training sessions and subsequently created in-depth guides for two sections of the Web site: the data uploader and the neighborhood creator. This demonstrates that by sharing research tools on the Internet, nonprofit organizations are better able to pool their resources. Rather than trying to offer GIS services on their own, Legal Services simply adapted the NKCA project for their own clients. The ease with which they adapted it to their own needs stems from the accessibility of the NKCA user interface. In other words, projects that can address the needs of several organizations (i.e., easy-to-use demographic data and maps at the local level) help strengthen the nonprofit sector as a whole.
2. Leveraged resources: The California Coalition for Rural Housing (CCRH) fits into a slightly different model. A statewide low-income housing coalition, CCRH provides technical assistance and research for its member organizations (mostly community development corporations). The NKCA staff worked with the CCRH staff to offer customized training periodically in Sacramento, California, and the surrounding region.[4] At the request of the CCRH staff, NKCA was adapted to better address GIS analysis in rural areas, where the size of census units and street addressing creates a special set of challenges (Goodchild 2000b).
3. User-friendliness: Municipal employees also exploit NKCA's free tools. As we learned with NKLA, agencies such as the Housing Department of the city of Los Angeles often have difficulty obtaining current, easy-to-use demographic and housing information. Much of this difficulty comes from within the city: they often face significant challenges securing data from coworkers and even steeper barriers from other city agencies. In the NKCA case, the location of data at UCLA helps increase legitimacy and circumvent the reluctance to share.

   This housing and demographic information is vital to the needs of city staff, as is shown by the feedback received from a planner in central California who works on housing and economic development issues:

   I help to administer federal funds allocated to the County from the U.S. Department of Housing and Urban Development (HUD). The HUD regulations require grant recipients to prepare and adopt a five year Consolidated Plan and a fair housing plan (the Analysis of Impediments to Fair Housing). These documents are the "road maps" that show HUD how the jurisdiction will prioritize its efforts with regards to distributing the federal funds and removing impediments to fair housing.

   A key component of both documents is the Demographics section, which describes the characteristics of the local population base, income levels and housing market. Thanks to the UCLA Neighborhood Knowledge program, I was able to create valuable maps that showed information such as concentrations of various ethnic groups, areas of high and low household incomes, areas with high poverty levels, and areas of high rental and ownership housing. I created customized maps showing large portions of the county and also specific communities of interest. I created approximately 36 maps, and have used 8 of them in the fair housing plan. We will be using some of the maps in the Consolidated Plan as well.[5]

This example is particularly interesting because it demonstrates precisely how maps are used in active urban-planning processes. It also illustrates the anonymous nature of WGIS: in this case, the NKCA staff had no direct contact with this individual. The staff did not conduct outreach in San Luis Obispo County and simply received the feedback through the Web site. There are similar case examples from other areas of California, especially the small northern cities. While many users require customized browsing experiences, some individuals can create extract data with little or no assistance.

Other cases of collaboration involve partnerships with statewide or national organizations. NKCA has had formal relationships with CCRH (affordable housing), the California Reinvestment Committee (fair lending), and InfoOakland (regional data intermediary and project of Urban Strategies Council). These partners offer feedback to the NKCA staff, interface directly with local users, and develop joint funding opportunities. In addition, the staff partnered with data intermediaries in San Francisco and New Orleans with the idea that Web site content could be shared among similar organizations. For example, the NKCA staff worked with the Greater New Orleans Community Data Center to create short educational tutorials aimed at "nonexpert" mappers. The NKLA, GNOCDC, and Urban Strategies Council are all part of a network of projects organized by the National Neighborhood Indicators Partnership (NNIP).[6]

I have already argued that partnerships play a critical role in project sustainability, but the NKCA case also illustrates a more subtle point. Particular relationships between individuals are the building blocks of these partnerships, and they are built in unpredictable ways. The virtual nature of WGIS accentuates these effects because of the emphasis on sharing of data and the ease of passing computer codes. In many cases, collaborative work occurs even without in-person meetings. For many who consider themselves "techies," this may be the preferred mode of collaboration. In addition, dichotomies of self-identity arise between those who consider themselves "geeks/coders/ techies" and "technophobes/nontechnical people." While these might be false and permeable distinctions, they often function as bonding mechanisms. The "geeks" from two different partner organizations forge bonds that enable them, when necessary, to transcend organizational boundaries.

Beyond the formal relationship that exists between, for example, a research institute and a city agency, other types of individual relationships complicate the situation. Individual staff members from each organization confront a bewildering set of pressures that may include the organizational mandate, manager-employee dynamics, institutional constraints, and simple interpersonal rapport. In some cases, especially when project success or failure can hinge on the acquisition of a single set of data, these unaccounted interpersonal factors become paramount. These processes can work to advance or inhibit project objectives. For example, a harmonious interpersonal relationship between software developers can lead to the sharing of data against the (formally or informally stated) wishes of their supervisors. Such sharing takes the form of partial datasets that can then be covertly used to further develop applications in ways that subsequently become appealing to both sides of the partnerships. In other cases, relatively simple data-sharing tasks are blocked for reasons that have nothing to do with technology but rather stem from interpersonal conflict or political maneuvering. Critical to these partnerships are "advocates" or individuals who will champion their partner organization to help sustain the collaboration.

The Centrality of the User Interface

In contrast to the ease with which people can now use mapping Web sites such as MapQuest or Google Maps, users and developers of community-based mapping systems face an array of challenges. Building on the critiques from the PPGIS literature, we know that nonexpert GIS users must have easy-to-use, intuitive interfaces that do not require excessive training or copious time to understand (Haklay and Tobón 2003). They also often require localized data, or at least the ability to easily combine their own data with system-wide base data. In addition, a digital divide (though perhaps diminished) still exists for many nonprofit organizations and low-income users. For those with limited access to broadband connectivity, software applications must have lightweight clients.

The Web interface is extremely important to end-users of community-based WGIS (Haklay and Tobón 2003). While nonexperts require simplified interfaces that remove unnecessary tools and functions, other users can benefit from uncluttered applications. Indeed, GIS professionals also face limited amounts of time to complete tasks. For all users, interfaces that generate efficient task completion reduce frustration and improve output. When community-based projects have "empowerment" as part of their mission, they endeavor not only to help people accomplish existing tasks but also build capacity. Capacity building leads to the acquisition of new knowledge or skills that can be transferred to other objectives. For example, the NKCA aims at educating people about the topics of affordable housing and fair lending while improving their geographic literacy.

Along with the need for proper terminology, there is a persistent need for ways to easily incorporate localized data in community-based GIS. Data quality is the crucial foundation in geospatial analysis (Aronoff 1989, Schuurman 2004), but collecting accurate reliable data can be a challenge in the CBO context. CBOs often rely on community service from students or people untrained in data collection, and often have limited budgets and time frames. There is, for example, a great need for cost-effective methods to integrate tabular, address-based survey information in GIS.

The NKCA features two unique applications that illustrate how cutting-edge technology particularly benefits users with limited technical capacity in novel ways (Steins 2003). The first is the "Data Uploader," a tool that provides a method for anonymous users to incorporate their own tabular data (e.g., a list of addresses in a spreadsheet) to create their own map layers. Uploading addresses is an important and routine procedure in desktop GIS, but there are two difficulties for the mapping novice. For one, it normally requires licensed GIS software. Secondly, using desktop software often generates considerable confusion and a significant failure rate.

To mitigate these challenges, the NKCA provides a four-step process that is comparable to uploading photos to send via e-mail. After uploading and naming their tabular data, users can then view their list of addresses as a point-based map. Moreover, they can compare their data to information included in the NKCA data library. For example, a community organizer from the San Francisco Bay Area wanted to know if his coalition of churches was in the same sections of the city that had large concentrations of African-Americans. Using his directory of churches, he uploaded the addresses into the NKCA, and then viewed those data points against a thematic map of ethnicity by census tracts. He found that several churches were clustered in sections of the city while others parts were relatively underserved. While this procedure certainly has methodological limitations, for his purposes, it was sufficient and, in fact, quite illuminating.

The second application—referred to as "Create your own neighborhood"—helps users define research areas and then quickly obtain summary statistics for a particular census tract or

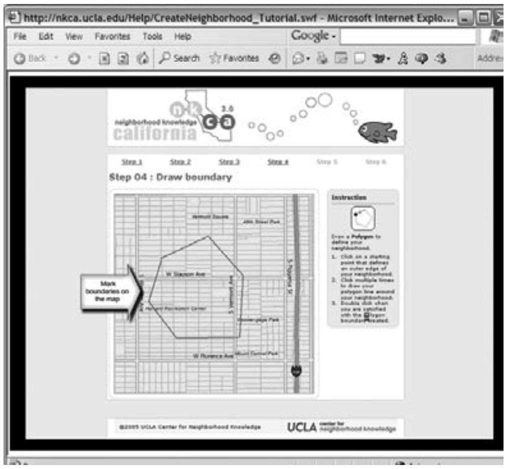

Figure 2. "Create Your Own Neighborhood" tool

group of census tracts. While an analogous query could be done using the American Factfinder from the U.S. Census, this tool has several advantages. First, while the Factfinder Web site only allows neighborhood selections based on menu-driven forms, the NKCA uses an interactive point-and-click method by which users see the census tracts or block groups they are interested in studying (Figure 2). Needless to say, very few people—professional or otherwise—are aware of the number of their census tract. Taking advantage of contextual cartographic clues such as main streets and physical landmarks helps users pinpoint their target areas. The second advantage of the NKCA application is that you can save your "neighborhood" in a profile and thus make it available for later queries or for use with the Data Uploader tool. Finally, the ability to share these neighborhood areas means that different users can distribute their results and use the tool as a collaborative, interactive way to define geographic boundaries. In training workshops, the NKCA staff has used this tool to help the CBO staff define the boundaries of their intended target area.

These two applications exemplify how WGIS technology can be adapted to perform functions previously unavailable to CBOs. Through the Data Uploader and "Create your own neighborhood" tools, we see how GIS technology can be effectively modified to benefit end-users. Geographers have made the case that GIS is not inherently rigid, but through rewiring can be adapted to meet unforeseen user requirements (Kwan 2002). "Writing the cyborg" entails dealing with the underlying technology directly; use of engaged, feminist approaches can make "GIS and geography a more equitable place not only for women but for many underrepresented and less powerful groups" (Schuurman 2002). Although the NKCA's data uploader tool does not address epistemological critiques, it does serve as an example of applied research that altered GIS technology. By opening a piece of the "black box" of ArcIMS and rewriting the code to make the uploading feature free to nonprofit users, the NKCA democratizes the ability to create point-based maps. This also illustrates the general point made by Craig (2005): that individuals (e.g., software developers) can make a lasting impact.

Finally, the NKCA emphasizes education. The driving philosophy behind the user interface is to teach users about spatial analysis as opposed to simply offering maps over the Internet. Throughout the Web site, context-sensitive help located in orange boxes gives definitions for geographic terms, offers examples of how maps might be used, and points to online tutorials and Flash-based GIS instructional materials. The project focuses on how spatially based social science research can be used for community action.

System Architecture and Flexible Development

The technical strategy in Web site development should correspond to the larger project objectives. In the NKCA case, a flexible technological back end enabled the creation of effective community partnerships and a dynamic user interface. By tinkering with the basic templates and architecture offered by commercial GIS products, a customized software and hardware platform opens the door for Web sites that better meet the needs of community-based GIS projects.

With the dual pressure of underfunding and onerous user requirements, it is vital that the development strategy makes the best use of limited resources. The Internet opens up the possibility of delivering community-based GIS services in a manner that can be highly cost-effective. By building database-driven Web applications with a modular programming approach, system developers can take advantage of reusable application components and create more extensible applications. Developing Web services also enables remote administration and, more important, the ability for system users to customize maps, upload data, and share files—in short, to access free mapping and analysis tools with a Web browser and an Internet connection. Although this type of development approach required skilled programmers, planning, and an initial investment, in the long run it may prove more sustainable for promoters of community-based GIS.

WGIS offers a new set of possibilities for system designers. Database-driven, scripted Web applications enable end-users to store, manipulate, and export spatial and personal information in ways that were previously prohibited by cost or hardware requirements. Likewise, the sheer amount of client (automated and solicited) feedback generated a large knowledge base of information.

Building on nearly a decade of user experiences from the preceding neighborhood-based GIS projects, the NKCA developers diligently compiled and incorporated feedback from a wide variety of people during regularly scheduled workshops, university and high school class sessions, meetings, academic conferences, and public demonstrations. Prioritizing the user also informed the design philosophy. Computer code was intended to operate in modules that could be extended in the future as needed to respond to changing technologies or users' needs. Online feedback mechanisms, quarterly community workshops, and ongoing evaluation tools helped provide fresh data to guide redevelopment. When the NKCA was first launched, there was little published or experiential knowledge about how nonexperts might use WGIS in their work. Many of the applications were experiments, and so it was important that they were built in a manner that was easy to redevelop and change as necessary. In fact, in 2005, version 2.0 of the NKCA launched and incorporated the large of amount of user feedback that the staff received in the NKCA 1.0 period (December 2002 to February 2005).

Unleashing the Potential of Community-Based WGIS

The NKCA case, along with other projects developed by the API/CNK, demonstrates the importance of user interface, application architecture, and partnerships in developing sustainable community-based WGIS projects. Moreover, these projects reveal the critical importance of attempts to alter existing technological products, the salience of the personal relationship behind partnerships, and the role of key individuals in PPGIS projects.

While the claim that "[c]artography has gone from spectator sport to participatory democracy" (Kelly 2005) might be slightly premature, WGIS does have the potential to alter the way that the general public uses geospatial data. At its best it can serve as a method for reducing the content aspect of the digital divide. As the following user indicates, it is especially effective when it transmits information in such a way that preserves complexity but keeps things simple:

> Thank you SO much for the presentation. I cannot tell you how great it was for me to see such a well-designed site. You-all have taken very complex information and made it accessible. Hey, are you closet librarians, or what? I see a lot of websites, and yours is absolutely, truly one of the best. It is a true service, and really is what bridging the digital divide is all about.[5]

If the NKCA and other WGIS projects can continue to meet the growing demand for easy-to-use maps and data, they will provide the type of contribution envisioned by optimistic proponents of PPGIS. They can also level the playing field between technocrats or professionals and community activists who lack either the time or expertise in data collection and analysis.

The NKCA project demonstrates that WGIS can deliver functionality that is "as easy to use as ordering a book or sending an e-mail" (Haklay and Tobón 2003). While many projects utilizing off-the-shelf WGIS contain overly complicated interfaces and nonintuitive iconography, this is not an inherent limitation. Rather, the ability to first dissect and then rebuild the system actually facilitates user-centered design and helps solve the problem of the increasing black-box nature of commercial GIS products. This strategy subverts the "trickster nature" of commercial GIS products, such as the geocoding process (Warren 2004). Although it seems counterintuitive for PPGIS projects (that often subsist on severely limited budgets), such Web-based projects must invest substantially in infrastructure development, user support, and interface design while simultaneously sustaining themselves financially and responding to the needs of their predominantly nonexpert users, who are often the individuals best positioned to contribute to community development projects.

Endnotes

1 As part of the development and outreach team, I participated in the coproduction of the various API projects. I personally served first as a junior team member on the NKLA project and then as the project manager for the NKCA project. In this capacity, the argument presented in this paper is undoubtedly rooted in the joint experiences of those involved in the creation and use of the various projects. Quotations, figures, and statistics have been used with the permission of the UCLA Center for Neighborhood Knowledge.

2 Neighborhood Knowledge California: http://nkca.ucla.edu; Neighborhood Knowledge Los Angeles: http://nkla.ucla.edu; Living Independently in Los Angeles (LILA): http://lila.ucla.edu; Healthy City: http://www.healthycity.org; UCLA in LA: http://la.ucla.edu.

3 Special thanks to Charanjeet Singh for providing Web-usage statistics.

4 The training information page for CCRH is located at http://www.calcruralhousing.org/ Home_NKCA.htm.

5 Quotations were provided anonymously to the NKCA through a Web-based feedback form.

6 Building on the social indicators movement in the 1970s (Kingsley 1999), NNIP is "a collaborative effort by the Urban Institute and local partners to further the development and use of neighborhood-level information systems in local policymaking and community building" (Urban-Institute 2005). The CNK staff profited from collaboration with these nationwide partners.

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Calibration of a Simple Rainfall-runoff Model for Long-term Hydrological Impact Evaluation

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Abstract: *The Long-Term Hydrological Impact Assessment (L-THIA) model is widely used to study direct runoff changes with respect to different land-use conditions. L-THIA was designed to assess the long-term impacts on the hydrology of a watershed for users who want to determine the relative change in runoff from one land-use condition to another. Some users, however, are interested in results that match observed stream-flow data, which includes both direct runoff and baseflow. A simple method of calibration of the L-THIA using linear regression of L-THIA predicted direct runoff and USGS-observed direct runoff values derived from hydrograph separation was developed and tested. The calibration model has been verified using three tests in the Little Eagle Creek watershed in Indiana. Results also raise additional questions regarding the factors that control runoff production and systematic underprediction of direct runoff by L-THIA as compared to actual observed direct runoff data.*

INTRODUCTION

Continued land development and land-use changes within cities and at the urban fringe present considerable challenges for environmental management. Hydrologic changes including increased impervious area, soil compaction, and increased drainage efficiency generally lead to increased direct runoff, decreased groundwater recharge, and increased flooding, among other problems (Booth 1991).

Hydrologic models, especially simple rainfall-runoff models, are widely used in understanding and quantifying the impacts of land-use changes, and to provide information that can be used in land-use decision making. Many hydrologic models are available, varying in nature, complexity, and purpose (Shoemaker et al. 1997). One such model, Long-Term Hydrological Impact Assessment (L-THIA), a simple rainfall-runoff model based on the U.S. Department of Agriculture's Curve Number (CN) method (USDA 1986), was developed to help land-use planners and watershed managers obtain initial insight into the hydrologic impacts of different land-use scenarios, including historic, current, and future alternatives (Harbor 1994). Like other models, L-THIA is based on empirical relationships that capture the main processes and controls on runoff, but do not account for all the conditions and controls specific to particular study sites, and do not predict the baseflow component of stream flow. Where close correspondence between predicted and observed runoff values is required, rather than simply a relative measure of change, it is necessary to produce a modified (calibrated) model.

Calibration of rainfall-runoff models with respect to local observational data is used to improve model predictability. When model results match observed values from stream-flow measurement, users have greater confidence in the reliability of the model. In the present study, a simple method based on univariate linear regression has been used to calibrate L-THIA, using land-use change data, model predicted direct runoff, and direct runoff derived from stream-flow data using hydrograph separation. This calibration approach is field-verified and can be used with any simple rainfall-runoff model, if there are observational data available. Interestingly, calibration and verification test results for the Little Eagle Creek watershed in Indiana show the usefulness of this approach in general and at the same time raise new questions about the sensitivity of L-THIA model predictions to land-use changes, precipitation, and selection of CN values.

L-THIA—A SIMPLE RAINFALL-RUNOFF MODEL

Modeling rainfall-runoff relationships can be complicated and time-consuming because of the numerous variables that are involved (Bhaduri et al. 2001). Models that capture many of the factors controlling runoff typically require extensive input data and user expertise. Some types of users, such as watershed managers or urban planners, need various levels of models to support decision making, including initial assessment tools that can produce results with minimal data and user expertise. Initial assessments can be a cost-effective way to identify areas of importance that can be targeted for further analysis using a more detailed model or field-based study. Providing users with a simple assessment model can help them reach decisions more quickly and efficiently than immediately performing analysis with highly detailed hydrologic models.

The L-THIA model, developed to fill the need for a simple assessment tool, has the capability to provide relative estimates of direct runoff and nonpoint source (NPS) pollution from different land uses (Bhaduri 1998). The L-THIA model details, utility, and applicability have been demonstrated in several studies (e.g., Leitch and Harbor 1999, Harbor et al. 2000, Bhaduri et al. 2000, Grove et al. 2001), and L-THIA is now widely accessible through a Web-based version of the model (http://www.ecn.purdue.edu/runoff, Pandey et al. 2000a, Pandey et al. 2000b). Even though most studies have used L-THIA to assess the relative impacts of land-use changes, the apparently low absolute runoff values (Grove et al. 2001) predicted by the model (in comparison to "runoff" values based on local stream-flow data) has been a concern for some users. Anecdotally, in L-THIA training workshops, a frequent question from users knowledgeable about local runoff data concerns the mismatch between L-THIA estimates and "real" runoff values. On further questioning, it becomes clear that the users are referring to average annual runoff depths back-calculated from stream-flow data, i.e., including both direct runoff and baseflow. In cases where the predicted runoff is compared to the stream-flow records, the main difference is presumably caused by the fact that the stream-flow record contains both direct runoff and baseflow components, while L-THIA predicts only the direct runoff part of the flow. Additional differences between actual (observed) direct runoff and L-THIA predicted direct runoff values can result from factors such as actual antecedent moisture conditions, evapotranspiration, generalized land-cover data, surface topography, and spatial and temporal variability of rainfall. The effects of these variables should not systematically change relative comparisons of runoff associated with land-use changes using the model. However, if the objective is to compare predicted to observed runoff values, which was not the original purpose of L-THIA, then discrepancies between model predictions and observed values based on stream-flow records should be expected. To compensate for this, calibration can be used to derive values that are adjusted to local observational data.

MODEL CALIBRATION

Calibration is a process of standardizing predicted values, using deviations from observed values for a particular area to derive correction factors that can be applied to generate predicted values that are consistent with the observed values. Such empirical corrections are common in modeling, and it is understood that every hydrologic model should be tested against observed data, preferably from the watershed under study, to understand the level of reliability of the model (Linsley 1982, Melching 1995). The calibration process can provide important insight into both local conditions and model performance; if correction factors are large or inconsistent across several study areas, this suggests that some significant component of the hydrologic system or its controls is being neglected.

Several methods of calibration are available based on methods such as artificial neural networks, multiple objective methods, linear, and nonlinear regression models (Cooper et al. 1997, Madsen 2000, Yu and Yang 2000, Elshorbagy et al. 2000, Ndiritu and Daniell 2001, Madsen et al. 2002). Choosing an approach depends on the purpose of the model, the model parameters or variables involved, how they vary, and how they affect the model results. A good understanding of the particular model and sound knowledge of hydrological processes is necessary for developing a reliable calibration method (Madsen et al. 2002).

Long-term rainfall-runoff models such as L-THIA need to be calibrated based on long-term trends rather than on individual events. Even though the model generates runoff values for each rainfall event, the values are summed for each year to produce total annual runoff yield. Similarly, for calibration, observed runoff values are summed to produce total annual runoff for the study area.

Calibration is achieved in two steps, separation of observed direct runoff from stream-flow data using hydrograph separation and then comparison of predicted and observed runoff values. Numerous analytical methods for hydrograph separation have been developed (Nathan and McMahon 1990, Arnold et al. 1995, Fury and Gupta 2002). Based on the objectives and the need for comparability and reproducibility, the standard U.S. Geologic Survey (USGS) baseflow separation model HYSEP (Hydrograph Separation) (Sloto and Crouse 1996) adapted from methods developed by Pettyjohn and Henning (1979) was used here.

The accuracy of baseflow separation depends on the length of stream-gauge record data that is processed. Longer periods of data provide more reliable separation than shorter periods, and average annual or average monthly values give better results than daily predictions. Thus, the calibration period should be longer (eight years or more) and the data used to calibrate should be standardized to account for the temporal variability of runoff that is caused by changes in rainfall and land-use conditions (Linsley 1982, Yapo et al. 1996). For L-THIA to predict temporal changes that match observational data, frequent land-use data are required. Typically, only current land-use and occasional historical maps are available. If land-use data could be obtained for each year for the whole duration of the runoff studies, it would provide the most accurate calibration of the model. However, because of the unavailability of frequent land-use data, a method of land-use data generation based on interpolation between two or more existing land-use datasets is developed and used here. This ensures that the model predicted runoff actually reflects temporal variation, and thus can be compared directly with the corresponding observed data for each year.

CASE STUDY: MODEL IMPLEMENTATION ON LITTLE EAGLE CREEK WATERSHED

Little Eagle Creek (LEC) watershed with a drainage area of 58.8 km^2 (22.7 mi^2) is an urbanizing watershed, located northeast of Indianapolis in central Indiana. The spread of the city outwards has resulted in increased development within the LEC watershed, causing significant land-use change, particularly forest converted to urban uses (Figure 1). In 1991, 70 percent of the watershed was developed (built), a 40 percent increase over the previous two decades (Table 1, Grove 1997).

Category	1973		1984		1991	
	mi^2	%	mi^2	%	mi^2	%
Developed	13.42	49.36	17.24	63.37	18.56	68.21
Undeveloped	13.77	50.64	9.96	36.63	8.65	31.79
Total	27.20	100	27.21	100	27.20	100

Table 1. Percentage of developed and undeveloped land uses in Little Eagle Creek derived from classification of Landsat satellite image from 1973, 1984, and 1991

This rapid change in land use resulted in water quality- and quantity-related concerns, which are central to the quality of life for the citizens of the community (Open House 1998, 1999). Indianapolis has been recognized as having outstanding development potential (Hedgcoth 2000), thus there are compelling reasons to study and understand the hydrologic impacts that future land development might have in this area.

Model calibration will improve L-THIA results by providing more reliable runoff predictions for future land-use conditions that can be used by urban planners and watershed managers for policy evaluations, and by decision makers in cases where zoning changes are requested. Previous studies of the LEC watershed have focused on the relative impacts of past land-use changes on direct runoff and nonpoint-source pollutants (Bhaduri et al. 2000). However, model predicted runoff values were significantly below stream-flow values (Grove et al. 2001) without calibration, and may not be sufficient for use in some decision-making cases.

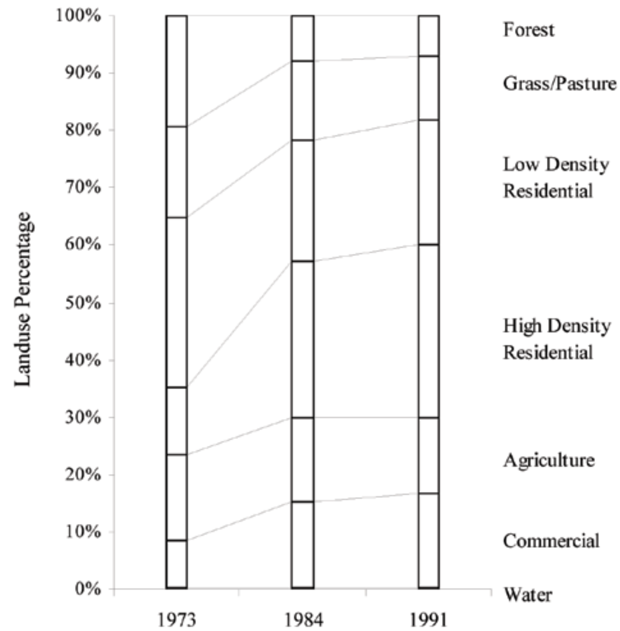

Figure 1. Land-use proportions in the LEC watershed during 1973, 1984, and 1991, derived from Landsat satellite data (after Grove 1997)

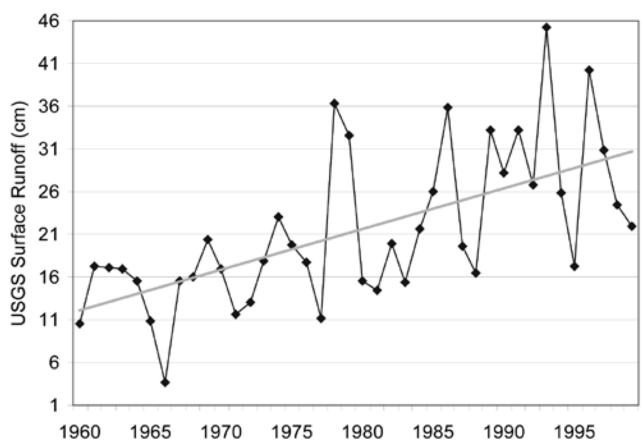

Figure 2. Long-term observed direct runoff trend in LEC watershed

CALIBRATION AND VERIFICATION OF THE L-THIA MODEL

The data used for the L-THIA analysis of the LEC watershed include land use based on remote sensing analysis for 1973, 1984, and 1991 (Grove 1997), Soil Survey Geographic (SSURGO) soil data developed by the U.S. Department of Agriculture, Soil Conservation Service (now Natural Resources Conservation Service) at 1:16,000 scale, long-term daily precipitation obtained from the National Climatic Data Center and the National Oceanic and Atmospheric Administration (NOAA 2002), and long-term daily stream flow from the national stream-flow database of the U.S. Geological Survey (USGS 2002) separated into baseflow and direct runoff. As a first step towards calibration, ArcView GIS was used to combine land-use and soil-grid data to generate curve numbers (CNs) for each land-use and soil combination. Once the area of each land-use and soil-combination classes was obtained from the three original land-use datasets (1973, 1984, and 1991), linear interpolation between 1973 to 1984 and 1984 to 1991 was used to estimate the areas of different land use and soil combinations for intervening years.

Four calibration and verification tests were designed to evaluate the model. In the first test, data from 1973 to 1982 were used for calibration and data from 1983 to 1991 were used to verify the model. In the second test, data from 1982 to 1991 were used for calibration and 1973 to 1981 were used to verify the model. In the third test, the dataset was divided into odd years and even years and odd years were used for calibration and the even years were used to verify the model. Finally, in the fourth test, calibration based on the whole dataset (1973 to 1991) was performed and compared with the other three calibration models. A comparative analysis between linear and nonlinear regression models for all four calibration tests was performed to examine which model would provide better predictions.

Once the initial data preparation was completed, a modified version of the Web-based L-THIA model was used to compute daily direct runoff values for the period 1973 to 1991. For runoff CN selection, normal antecedent moisture condition (AMC II) was assumed. Predicted daily runoff values were then summed to produce total annual runoff for each year and were used in further analysis. Observed direct runoff values were also summed to produce total annual runoff for each year.

RESULTS AND DISCUSSION

The stream-flow record is often the only practical source of information for model comparison and calibration. In the LEC watershed, the long-term observed direct runoff shows a strong increasing trend (Figure 2). From the early 1970s to early 1980s, there were significant changes in land use in the form of more urban development, as compared to the mid-1980s to late 1980s (Figure 1). Corresponding to this change in land use, one would expect to see an increase in observed direct runoff flow in streams during this time, but the stream-flow response was not immediate. It appears as though changes in land-use conditions had no immediate effect on stream flow; rather, it was a slow response that increased cumulatively. In the mid-1980s to late 1980s, even though the rate of urbanization subsided compared to the rate of the previous decades, stream flow continued to increase. Possibly, this resulted from "improvements" or changes within areas already developed, such as an increased, connected impervious area, and other drainage works that increased direct runoff through stormwater drainage pipes.

A comparison of linear and nonlinear regression models used to fit the observed and predicted data showed that a linear model was the best model, with the highest R^2 values (Table 2), suggesting more complex models are not necessary in this case. Thus, a linear regression model was adapted here. To test the calibration models developed in this study, two measures were used: Mean Absolute Error (MAE), the average value of residuals that is used as a measure of the closeness of fit of the regression model; and R^2, which measures how much of the variability in model predictions is explained by the regression model. Results from four calibration tests are summarized in Table 3. Test 1 (R^2 = 0.85, MAE = 0.52) produced the highest positive correlation between observed (USGS) and predicted (L-THIA) direct runoff values followed by test 4 (R^2 = 0.68, MAE = 0.75). Tests 2 and 3 both display a moderate correlation with relatively lower R-squared values and higher MAE values. Figures 3 to 6 show comparisons of observed, predicted, and calibrated-predicted direct runoff values for calibration tests 1 to 4, respectively. All four models perform very well in improving the predicted values for the calibration period.

The performance of the calibrated models was then assessed by comparing predicted, calibrated direct runoff values with USGS direct runoff not used in calibration. An analysis of the difference between the predicted (L-THIA) and observed (USGS) mean values of runoff, and a test of significance using t-test were used. Even though statistically the two means were found to be the same for all the calibration models, at 95 percent confidence level, analysis of Difference in Mean (DM) shows that when compared

Model	R^2			
	Test 1	Test 2	Test 3	Test 4
Linear	0.85	0.59	0.55	0.68
Square root – Y	0.84	0.58	0.54	0.67
Exponential	0.82	0.57	0.51	0.65
Square root – X	0.82	0.59	0.55	0.65
Logarithmic – X	0.77	0.58	0.55	0.62
Double reciprocal	0.74	0.54	0.47	0.55
Reciprocal – Y	0.72	0.51	0.45	0.58
Reciprocal – X	0.64	0.55	0.51	0.54

Table 2. Linear versus nonlinear models (test 1—data from 1973–1982 used to calibrate and data from 1983–1991 used to test the model; test 2—data from 1982–1991 used to calibrate and data from 1973–1982 used to test the model; test 3—data from odd years used to calibrate and data from even years used to test the model; test 4—data from 1973–1991 used to calibrate the model and tested against previous models)

Calibration		R^2	Level of Confidence (%)	Mean Absolute Error	Calibration Equation*
Name	Period				
Test 1	1973–1982	0.85	99	0.52	$Q_c = (Q_p - 0.21)/0.57$
Test 2	1983–1991	0.59	99	0.77	$Q_c = (Q_p - 0.68)/0.43$
Test 3	Odd Years (1973–1991)	0.55	95	0.88	$Q_c = (Q_p - 0.37)/0.39$
Test 4	All data (1973–1991)	0.68	99	0.75	$Q_c = (Q_p - 0.66)/0.47$

Table 3. Statistical analysis results for calibration tests
* Q_c= calibrated runoff, Q_p= predicted runoff

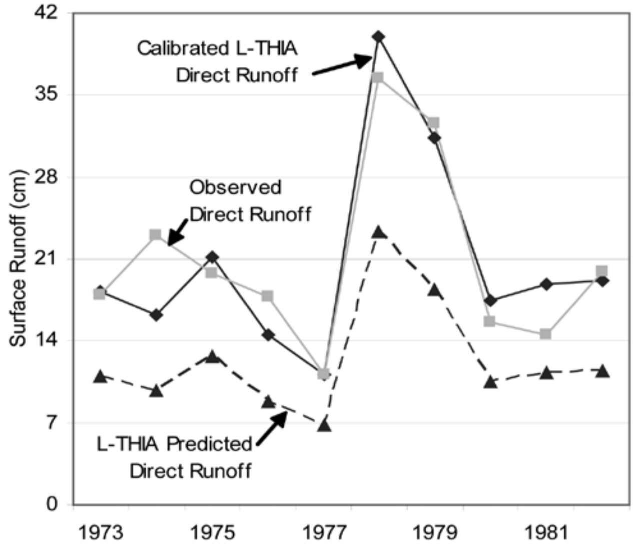

Figure 3. Comparison of predicted, observed, and calibrated runoff from test 1

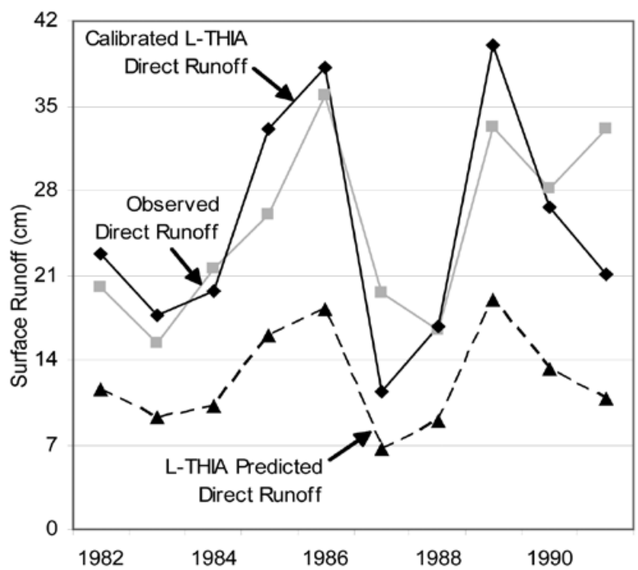

Figure 4. Comparison of predicted, observed, and calibrated runoff from test 2

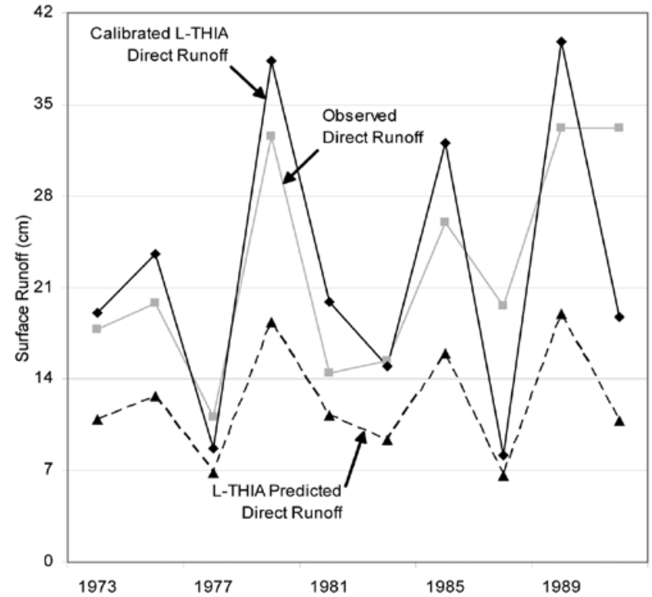

Figure 5. Comparison of predicted, observed, and calibrated runoff from test 3

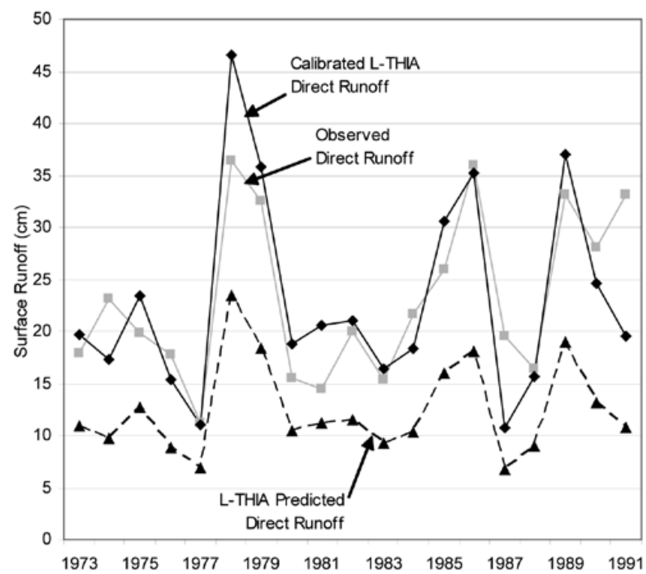

Figure 6. Comparison of predicted, observed, and calibrated runoff from test 4

with the observed runoff, test 1 underpredicts the direct runoff by 18 percent while test 2 overpredicts direct runoff by 19.5 percent (Table 4). Interestingly, test 3 predicts a runoff mean that is close to the observed runoff; however, the regression model used in test 3 does not have a very strong correlation with the observed runoff, and it also has higher MAE, suggesting that this may not be the best model to use for future land-use scenarios.

Verification		Percentage DM	t	Level of Confidence (%)
Name	Period	(Mo - Mp)*		
Test 1	1983–1991	18	-1.35	99
Test 2	1973–1981	- 19.5	1.13	99
Test 3	Even Years (1974–1990)	0.7	-0.22	95

Table 4. Statistical analysis results for verification tests
* Mo- mean of observed (USGS) direct runoff; Mp- mean of predicted (L-THIA) direct runoff after calibration

It is not surprising, however, that test 1 is underpredicting runoff for the verification period, 1983 to 1991, because the calibration model that is used for this test was developed from a period when the land-use changes were more pronounced, but the direct runoff component of stream-flow response to land-use changes was not immediate. This resulted in a smaller shift required to calibrate the model. The calibration model developed for 1982 to 1991 needed a larger shift to achieve calibration and when applied to an earlier period, it overpredicted runoff (by 19.5 percent) as compared to the observed direct runoff. To neutralize this problem, it is necessary to calibrate using the whole range of data, as was the case with the calibration test 4. Clearly, for best overall predictability, calibration using the entire dataset should be used. For the LEC watershed, the regression equation that best explains the variability in predicted runoff using the entire data set is

$Q_c = (Q_p - 0.66)/0.47$
where
Q_c = calibrated L-THIA prediction and
Q_p = predicted L-THIA values.

CONCLUSIONS

This study presents the development and testing of a simple calibration approach based on observed direct runoff values derived from readily available stream-gauge data available over the Internet; no complicated processing is required in the calibration process and, other than the stream-gauge data, no additional information is required beyond that used in an L-THIA model run. On the Web-based version of the L-THIA model, the calibration process could be automated based on the availability of stream-flow data. This will enable those users interested in results that are closer to the observed values to use calibrated L-THIA predictions. This calibration approach could be used for other rainfall-runoff models.

L-THIA model predictions are found to be approximately 50 percent lower than actual observed direct runoff for the LEC watershed. This difference could be attributed to several reasons. First, the L-THIA model is based on the CN method, which was initially developed for agricultural and natural watersheds, and extending it to "extensive" urban watersheds, for which the existing CNs are not representative, can cause the model to predict low runoff. Secondly, in the CN method, runoff is directly proportional to precipitation with an assumption that direct runoff is produced after the initial abstraction of 20 percent of the potential maximum storage. The initial abstraction represents all losses before runoff begins, and includes water retained in surface depressions, water taken up by vegetation, evaporation, and infiltration. This 20 percent was based on several studies of small watersheds, by determining the best-fit relationship between potential maximum storage and initial abstraction. However, the regression plot of this best fit shows a large scatter (Hawkins et al. 2001), reflecting a large variation because of the inherent variability of soil infiltration and land-surface characteristics. Moreover, this assumption may not be valid for urban watersheds, where even small rainfall events produce significant direct runoff because of increased efficiency of surface drainage through storm-drainage systems. The storage factor presumably becomes less and less significant as more and more surface area is paved. The same concern is addressed by Hawkins (2001), whose studies suggest that 5 percent is more representative than 20 percent for triggering runoff from rainfall events. Implementing 5 percent as the runoff triggering limit should result in L-THIA capturing the smaller, but more frequent and significant, rainfall events that produce runoff.

A final reason for underprediction of runoff may be the quality of the land-use data used. If the land-use data are not representative of actual ground conditions, runoff predictions based on this will be skewed. As annual land-use data are rarely available, there is a good chance that land-use change is not only generally represented by the data, and significant changes may occur more quickly than captured by linear interpolation. If the pace of land-use change or intensification is not captured in the available data, then L-THIA results should underpredict observations during periods of urbanization.

A thorough analysis of the causes of L-THIA underprediction is beyond the scope of this paper. Whatever the reason for the discrepancy, calibration makes L-THIA model predicted direct runoff match observed direct runoff. However, the relative impacts predicted by a calibrated L-THIA model will remain the same as those predicted by an uncalibrated L-THIA model. Four calibration tests were carried out for the LEC watershed using different datasets for calibration and verification. All four tests produced results that improved L-THIA predictions compared to actual observed runoff. Based on statistical analysis and long-term observed direct runoff trends, however, the calibration model developed with the entire dataset will best serve long-term hydrological studies and prediction of impacts of future land-use conditions. Application of this calibration equation to watersheds other than the LEC watershed, even those with similar characteristics, is not recommended at this stage. Further studies to determine the robustness of the calibration equation are needed to determine whether separate calibration is needed for each watershed. The calibrated L-THIA model can now be used to understand the impacts of future land-use conditions, so that proactive measures can be taken to control negative impacts.

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Spatial Data Infrastructure (SDI) and E-governance: A Quest For Appropriate Evaluation Approaches

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Abstract: *A spatial data infrastructure (SDI) can be conceived as the geo-information technology realm of e-governance. SDI evaluation approaches are maturing with a steady increase in research instruments, from questionnaires to case studies to the use of theoretical grounding and, most recently, to theory generation. Still, however, there is considerable difficulty with identifying and measuring benefits, as well as the challenge of managing the increasing complexity as we move from an SDI data-centric to a service-centric and, finally, to a governance-centric perspective in SDI evaluation. The primary objective of this paper is to explore the question, "Which SDI evaluation approaches are appropriate in the dynamic and volatile environment of e-governance?"*

We introduce a taxonomical lens from information-systems evaluation research to classify existing SDI evaluation approaches as "control," "learning," "sense-making," and "exploratory" evaluations. We review the e-governance literature with emphasis on the still nagging disagreement regarding the implications of information technology in governance. We suggest that governance-centric SDI evaluation should be exploratory in nature, at least in the first instance, and should encompass the degree of convergence of rationalities and interests among different spheres of governance.

INTRODUCTION

The *Oxford English Dictionary* defines evaluation as *"the action of evaluating or determining the value of something or somebody, or the action of estimating the force of probabilities, evidence."* Evaluation is a natural activity for human beings. Most people are inclined to consider carefully before deciding on a course of action, and often individuals and organizations need to demonstrate that decisions made were rational.

> Evaluation is endemic to human existence. Whether consciously or not, people evaluate the products and processes of their labour. Food, drink, appearance, social interactions etc. are constantly being evaluated by someone or something. . . . Evaluation is undertaken as a matter of course in the attempt to gauge how well something meets a particular expectation, objective or need. People, it seems, have an insatiable appetite or curiosity for such things. . . . Evaluation is apparently an important and intrinsic property of the process of understanding, which in turn is a prerequisite for, or a prelude to, a carefully considered action.
> (Hirschheim and Smithson 1999, 381)

The growth of information system (IS) evaluation research comes as no surprise. In commercial organizations, the sheer size of information technology (IT) investment and management's expectation for the highest possible future gains account for the unabated interest in IS/IT evaluation (e.g., Willcocks and Lester 1999). Specialized academic journals have provided a forum for academics and practitioners to debate evaluation theories, methods, and data relevance. Despite decades of attention to IS/IT evaluation, however, evaluation research seems unable to achieve a soft landing (Berghout and Remenyi 2005).

Public-sector organizations face similar concerns. E-government and e-governance initiatives require extensive IS/IT investments to make the full range of government activities available electronically. Investments in information technology for government in most industrialized nations are estimated to be greater than 1 per cent of the gross domestic product (Petricek et al. 2006). However, attempts by either international organizations (e.g., OECD 2003) or by private-sector consultancies (e.g., Accenture 2003, 2004) to assess e-government internationally are considered methodologically questionable and too narrowly focused on government electronic services (Petricek et al. 2006). Bannister (2004) refers to evaluations by international organizations as "beauty contests" of countries trying to measure how they are doing against the competition with the result that what gets scored is what can be easily measured, or even measured at all.

Evaluation research has also received considerable attention in the geographic information community (Clapp et al. 1989; Didier 1990; Johnson 1995; Krek and Frank 2000; Krek 2000; Lopez 1998, 1997; Nedovic-Budic 1998; Rodriguez et al. 2002). With the reconceptualization of interorganizational GIS as spatial data infrastructures (SDI) in the 1990s, the complexity of the object of evaluation, SDI, increased substantially. SDIs have emerged as a significant area of development with geographic information underpinning wider government strategies and initiatives such as e-governance. SDI evaluation approaches have matured with a steady increase in research instruments, from questionnaires to case studies to the use of theoretical grounding (e.g., Craglia and Johnston 2004; Crompvoets et al. 2004; Delgado et al. 2005; Hyman et al. 2001; Masser 2000, 1999; Onsrud 1998; Pavlova et al. 2002; Rodriguez 2005; Steudler 2003). However, there is still considerable concern related to the difficulty with identifying and measuring benefits, and the increasing complexity as we move from a SDI data-centric to a service-centric point of view (JRC 2006, Grus et al. 2006). Furthermore, with SDI now broadly understood as the geo-IT realm of e-governance, we contend that a shift to a governance-centric SDI evaluation is warranted.

The remainder of the paper is organized as follows. We first introduce a taxonomy of IS/IT evaluation orientations proposed in the information systems literature. Then we classify SDI evaluation approaches using this lens and review the e-governance literature. We outline a governance-centric SDI evaluation perspective and present some brief conclusions and suggestions to develop further research.

INFORMATION SYSTEMS AND EVALUATION

The most widely accepted definition of IS/IT evaluation in the literature (Doherty and King 2004, Walter and Spitta 2004, Willcocks 1992) is: *"process of establishing by quantitative and/or qualitative techniques the worth (or value) of IS/IT projects to the organization."*

Academics and practitioners in IS/IT are in widespread agreement about the need to evaluate. The vehicle for undertaking such an evaluation, however, is still far from clear. Over the years, many organizations have met with considerable difficulty when attempting to estimate ex ante the benefits of IT adoption in the hope of justifying related expenditures (Farbey et al. 1999, Weill and Broadbent 1998). The same difficulty arises whenever project managers are obliged to show ex post the financial benefits already reaped from implementing such systems and technologies (Farbey et al. 1999a, Irani 2002). Effectively, organizations often find themselves unable to estimate and provide evidence for the benefits that resulted from adopting information systems and technologies (Avgerou 2000a, Parker et al. 1988). When benefits are reported in financial analyses, the assessment of nonfinancial and intangible benefits, which are apparently more extensive than the tangible ones, is limited or omitted. Thus the process of evaluating the consequences and impacts of adopting these systems and technologies is flawed and the justification of investing in such actions is hindered (Renkema and Berghout 1997, Smithson and Hirschheim 1998).

Numerous studies on the matter have been carried out for more than four decades. These studies have had the common goal of defining the principles and criteria for the assessment of the importance of implementing these systems and technologies (Renkema and Berghout 1997). The earliest studies on systems and technologies assessment began in the 1960s (Frielink 1961). The most recent ones focus on the assessment of systems that offer online business support (Gengatharen and Standing 2004, King and Liou 2004). In practice, there are at least three different kinds of evaluation: *"there are formal evaluation practices promoted by organizational rules and structures, informal practices implemented by stakeholders involved, and finally academic recommendations which in many cases recognize the delicate nature of evaluation but are not 'used' in practice."* (Serafeimidis and Smithson 2003, 252)

In general, IS/IT evaluation attempts have sought to measure how efficiently and accurately the proposed solutions, once they were adopted, met or did not meet the anticipated needs of the organization for which the system or technology was being developed. The complexity of present assessments is directly related to the fact that they must take into consideration the different contexts in which an adopted IS/IT solution originates. In this regard, each context seems to be conditioned by its own set of rules and characteristics and by a unique social and/or organizational culture (Lundell and Lings 2003, Serafeimidis and Smithson 2003).

Evaluation approaches in Information Systems

Many factors need to be considered when selecting a suitable evaluation approach. The first factor is related to timing. According to several authors (Doherty and King 2004, Farbey et al. 1999, Hirschheim and Smithson 1999, Walter and Spitta 2004), there are three different moments to perform evaluations: *"A priori"* (where the ex ante evaluation is defined as an assessment needed to decide whether to implement the project and—especially—to justify it), *"during"* systems or technologies development or implementation, and *"a posteriori,"* where the ex post evaluation attempts to demonstrate whether or not the adopted solutions produced the expected results and gains.

The second factor influencing the evaluation approach is its role. The role of the evaluation depends on the level (status of evaluators) at which it is carried out, or even more important, on the point of view taken in the analysis (Seddon et al. 1999). There is no single "optimal level" from which one may ideally conduct an evaluation. The level can change from one evaluation to the next. What is most important to remember is that different factors have different responsibilities, interests, and value systems, factors that can greatly influence the outcome of an assessment (Smithson and Hirschheim 1998).

The third important factor is the complexity and significance of the IS/IT evaluated. When IS/IT are complex and pervasive sociotechnical systems, such as SDI initiatives, their life cycles tend to extend over long periods of time, and the required investment appears to be defined as a program of social action (Farbey et al. 1999). In such cases, there is a ambiguity and a lack of structure in evaluation approaches to take into account the diversity of contextual situations encountered. This ambiguity is caused by two key factors: "*lack of clearly understood and agreed objectives and a lack of knowledge as to the potential impact of the IS, and hence a lack of knowledge of cause and effect.*" (Ibid., 196)

A taxonomy of IS evaluation approaches

Critical assumptions of IS/IT evaluation approaches can be defined by analyzing together the factors presented previously: the degree of clarity (or certainty) of IS/IT objectives and the degree of clarity (or certainty) regarding their potential impact. The clarity and perceived attainability of the IS/IT objectives—as well as of their evaluation—can vary from a consensual situation, where objectives are clear and widely accepted, to a nonconsensual situation, characterized by multiple interests and ambiguity. On the other hand, the impact on the organization of the anticipated investment can be perceived differently at different organizational levels, operational or strategic (Serafeimidis and Smithson 2003).

Depending on the level of uncertainty as to the objectives and as to cause and effect, four possible evaluation orientations are suggested: control evaluation, evaluation as learning, as sense making, and exploratory evaluation (Table 1). They are discussed in terms of their *nature* (as answer, learning, dialogue, and idea machine), in terms of their *purpose* (goal monitoring, experimenting, consensus building, and exploration), as well as in terms of the *evaluator role* (auditor, knowledge creator, facilitator, catalyst) in the process. Typical examples are given for each particular orientation.

Evaluation as control. In this orientation, the quantitative expected objectives of the investment in IS/IT as well as their impacts seem clear. Thus, it appears possible to establish an organizational consensus around them. Taking place at the operational level, this kind of evaluation mostly considers financial and technical issues and functions as an "answer machine." It supports rationalistic decision models and analysis about efficiency and effectiveness of IS/IT investment (e.g., Aladwani 2002, Averous and Averous 1998, Brynjolfsson and Hitt 1999, Cameron and Whetten 1983, Chin and Lee 2000, Davis 1989, DeLone and McLean 1992, Saleh and Alshawi 2005). The objective of the evaluation is goal monitoring; evaluators act as auditors controlling, ranking, or assessing success. Mostly quantitative issues are considered while social and intangible issues are either ignored or handled prescriptively. The classical example of "evaluation as control" is return on investment (ROI), a popular method with organizations with tight financial discipline. ROI approaches are usually performed by accounting staff for efficiency-seeking projects in well-defined circumstances, where both the goals and the anticipated affects of the investment are clear and certain.

Evaluation as learning. The expected outcomes seem clear, but their strategic achievement and impacts appear uncertain or difficult to predict. In this case, the organization needs to be flexible and open to individual and organizational learning and change (Argyris and Schön 1996, Boonstra 2004). The IS/IT evaluation operates as a feedback instrument, involving a social and critical process of inquiry, interpretation, and debate (Walsham 1999). It contributes to decreasing uncertainty of strategic changes (Symons 1993, 1991) and functions as a "learning machine." The objective of the evaluation is to experiment, while evaluators act as knowledge creators who increase the knowledge capital through experimentation. The classical example of "evaluation as learning" is cost-benefit analysis (CBA). CBA can be conceived as a variation of ROI where the costs and benefits (effects) are difficult to quantify and are substituted by surrogate measures.

Evaluation as sense making. In this orientation, there is no consensus about IS/IT expected objectives; they seem unclear and unpredictable. At an operational level, the links between actions and their potential impacts on organization are nevertheless seen as reasonably predictable. This kind of evaluation attempts to assemble informal and tacit information as well as formal information and functions as a "dialogue machine." The goal is to reach consensus concerning the objectives, with the evaluator acting as a facilitator in the process. Examples of sense-making evaluations are methods, such as prototyping and simulation. A prototype form of a system is used as a basis for experiments and a platform for sharing views to test and modify the system and its impacts before engineering the full version.

		Uncertainty as to cause and effect	
		Low	High
Uncertainty as to objectives	**Low**	*Evaluation as control* Answer machine Goal monitoring Evaluator as auditor e.g., ROI	*Evaluation as learning* Learning machine Experiment Evaluator as knowledge creator e.g., CBA
	High	*Evaluation as sense making* Dialogue machine Consensus building Evaluator as facilitator e.g., simulation, prototyping, etc.	*Exploratory evaluation* Idea machine Exploration Evaluator as catalyst e.g., Value analysis

Table 1. Orientations of evaluation adapted from Farbey et al. 1999 and Serafeimidis and Smithson 2003

Evaluation as exploratory practice. In this orientation, there is neither consensus about IS/IT expected objectives nor about their strategic achievement and impacts. In an exploratory evaluation, participants attempt to generate ideas and experiences and aim to understand and explain a highly uncertain situation. Exploratory evaluation functions as an "idea machine" for the definition of new paradigms, new organizational forms, and new behavioral norms. For Serafeimidis and Smithson (2003, 259), *"exploratory evaluation changes the schemas of the stakeholders and the assumptions that influence them."* Exploratory evaluation becomes a key mechanism for participation and social transformation. Evaluators act as catalysts driving required changes. An example of "evaluation as exploratory practice" is value analysis, a method based on the notion that concentrating on the value added is more important than focusing on cost saved.

The premises of exploratory evaluation stand at the opposite end of the spectrum from those of control evaluation. The positivist assumptions informing control evaluation are compared with the interpretive assumptions underlying exploratory evaluation, in terms of ontology, epistemology and related research methods (Table 2).

The power of interpretive approaches has been emphatically established both theoretically and empirically in the information systems literature (Walsham, 1993), in GIS implementation in organizations (Petch and Reeve, 1999), as well as in understanding the implementation dynamics of information infrastructures that span numerous contexts spread out globally (Ciborra et al. 2000).

SDI EVALUATION APPROACHES AND E-GOVERNANCE

Evaluation research has received considerable attention in the GIS community (Johnson 1995; Krek and Frank 2000; Krek 2000; Lopez 1997, 1998; Didier 1990; Rodriguez et al. 2002; Clapp et al. 1989; Nedovic-Budic 1998). With the reconceptualization of interorganizational GIS as SDI in the 1990s, the complexity of the object of evaluation, SDI, as well as of the process of evaluation increased substantially. SDI evaluation has focused either on directly assessing actual SDI projects (Craglia and Evmorfopoulou 1999, Kok and Van Loenen 2005, Masser 2000, Pavlova et al. 2002), on following the evolution of SDI initiatives (Craglia and Johnston 2004, Crompvoets et al. 2004, Hyman and Lance 2001, Onsrud 1998), as well as on comparisons (Craglia and Evmorfopoulou 1999; Masser 2000, 1999; Nedovic-Budic et al. 2003; Pauknerova et al. 2003; Pavlova et al. 2002). Conceptual studies investigated the relationship between evaluation criteria and different SDI hierarchical levels involved (Steudler, 2003) or focused on readiness issues related to technological, economical, communicational, and organizational factors (Delgado et al. 2005), or explained the complexity and multifaceted nature of SDIs as well as of their evaluation (De Man 2005). Rodriguez (2005) proposed a structured theoretical tool that views SDI evaluation as an involved process of socially constructing the infrastructure.

However, there is still considerable concern related to the difficulty with identifying and measuring benefits, and the increasing complexity as we move from a SDI data-centric to a service-centric point of view. The methodologies, implicit and explicit assumptions, as well the generalizability of evaluative frameworks, and the importance of contextual factors in future SDI evaluation efforts are still unclear (JRC, 2006, Grus et al. 2006). With SDI now broadly understood as the geo-IT realm of e-governance, a further challenge is the shift to a governance-centric SDI evaluation. In the remainder of this section, we classify SDI evaluation approaches using the taxonomy introduced previously. We then highlight some of the ambiguities that afflict the e-governance literature.

Taxonomy of SDI evaluation approaches

SDI evaluation efforts to date have had various scopes (regional, organizational, national, global, conceptual) and various study goals (performance measurement, monitoring of dynamics, consensus building, learning lessons, understanding) and have used various methods (automatic registration of events, questionnaires, Web site surveys, computer simulation, prototyping, case studies, and theory). The focus of the evaluation has been mainly on data, services, and SDI management issues (Table 3). When governance issues, such as legal framework, financing, private-

	Research paradigms in IS/IT evaluation	
	Positivist	**Interpretive**
Ontology	The true nature of reality can be obtained by testing theories about actual objects, processes, and structures in the real world.	The world is produced and reinforced by humans through their action and interaction.
Epistemology	Verification of hypotheses through rigorous empirical testing. Search for universal laws and principles. Tight coupling among explanation, prediction, and control.	Understanding of the phenomenon from the participant's perspective, in its natural setting, through interpretation of its meanings and actions.
Related Research Methods	Formal propositions, quantifiable measures of variables, hypothesis testing, drawing inferences from a sample to a stated population.	In-depth case studies and ethnographies.

Table 2. Positivist and interpretive research paradigms, adapted from Khazanchi and Munkvold (2003)

Author	Scope	Goals	Methods	Focus
Onsrud (1998)	Global	Understand SDI scope, nature, and extent	Questionnaire	Data
MetroGIS (2004)	Metropolitan	Performance measurement	Automatic registration of "events"	Data
Crompvoets et al. (2004)	Global	Performance measurement of clearinghouses	Internet browsing, measurement of characteristics	Data use management
Delgado et al. (2005)	National	Monitor dynamics	Fuzzy theory, questionnaires	Data management
Vandenbroucke (2005)	Supranational	Monitor dynamics	Experts' feedback, examination of Web sites	Data services management Some governance issues
Kok and van Loenen (2005)	Organizational	Assessment of organizational context	Case studies, organizational change theory	Management
Halsing et al. (2006)	National	Cost-benefit analysis	Computer simulation	Data services management
Giff and Coleman (2003), Masser (2003)	Few developed nations	Learn lessons from others	Case study	Management Some governance issues
Weiss (1998)	National	Self-evaluation	Workshop	Management
Kuhn et al. (2000)	Subnational	Consensus building	Prototyping	Data services management
Giff (2005)	Conceptual	Evaluate funding models over time	Computer simulation	Model's sensitivity to environment
Rodriguez (2005)	Conceptual	Understand dynamics of implementation	Case studies, Delphi, grounded theory	Efficiency Effectiveness Understanding

Table 3. Summary of selected SDI evaluation approaches

sector involvement, the importance of industry associations, and political support, etc., were taken into account, the approach has been descriptive and/or normative (e.g., Vandenbroucke 2005, Giff and Coleman 2003, Masser 2003).

This summary gives a useful snapshot of the increasing diversity in terms of evaluation scope, goals, methods, and focus taken by various authors ever since Onsrud (1998) conducted the first global SDI evaluation. This summary, however, does not make explicit the gaps that should be filled by further evaluation research, especially as we move to a *holistic governance-centric SDI evaluation* perspective. We argue that the taxonomy of IS evaluation approaches, summarized in Table 1, provides a richer lens though which to view these SDI evaluation efforts. In this section, we classify these examples based on the level of uncertainty regarding the evaluation objectives and the uncertainty regarding the cause and effect. The first example given in each class can be considered an ideal type (archetype) for the class, while the other examples may have some (minor) degree of overlap and intersection with other classes.

SDI control evaluation. MetroGIS (2004) can be considered an exemplar for SDI control evaluation. MetroGIS is a regional initiative serving the Minneapolis–St. Paul (Minnesota) metropolitan area. It is a voluntary collaboration of local and regional governments, with partners in state and federal government, academic institutions, nonprofit organizations, and businesses with the purpose to facilitate widespread sharing of geospatial data. The annual evaluation is mainly based on automatic registration of specific and most easily quantifiable outcomes that include visits to a DataFinder, number of data downloaded, frequently downloaded datasets, identification of entities downloading data, the number of DataFinder publishers, etc. Performance measures of benefits to data producers have not yet been quantified, while nonquantitative instruments, such as testimonials, are expected to gauge ultimate outcomes, such as improved decision making and better service to the public (ibid.). Performance results are reported annually by MetroGIS staff to the MetroGIS Policy Board, with the board acting as auditor. The MetroGIS (2004) objective is annual performance measurement for continuing revision of the program. The cause-effect relationship is clearly articulated, as the relationship between allocated resources and outcomes, the latter codified as ten performance measures.

The periodic assessment of clearinghouses at distinct epochs by Crompvoets et al. (2004) can also be considered a SDI control evaluation, albeit at a global scale. In this case, the complexity of "going global" was reduced by focusing on national clearinghouses as representative of national SDI initiatives. In this way, the relationship between cause (SDI development) and effect (use, management, and content of clearinghouses) was rendered clear and certain. Specific and quantifiable clearinghouse characteristics were monitored through Web browsing as well as through contacting local experts and Webmasters. A similar approach was adopted by Delgado et al. (2005) and Vandenbroucke (2005) at a national (Cuba) and transnational (European Union) level. While the issues considered in these studies were more complex—they encompassed organizational, legal, and financial aspects—the cause-effect relationship was clear and the objective certain. For example, Delgado et al. (2005) attempted to capture progress in SDI readiness through the use of questionnaires and fuzzy theory, while Vandenbroucke (2005) monitored the impact of the INSPIRE directive and the compliance of EU member states through feedback from experts, visits of Web sites, and review of reports and publications. Kok and van Loenen (2005) also assumed a clear causal relationship between the level of national SDI success and four organizational indicators, which they tested using two case studies, the Netherlands and the United States.

SDI learning evaluation. The cost-benefit analysis (CBA) of The National Map, carried out on behalf of the U.S. Geological Survey can be considered an exemplar for SDI learning evaluation (Halsing et al. 2006)**.** The objective of the study was clear: to estimate and analyze the costs involved in building, maintaining and distributing The National Map and the various benefit streams expected from its existence. Lack of precedents for this kind of analysis necessitated a novel computational model that simulated the number of users, application innovation, and diffusion, as well as changes in the net benefits of implementing spatial data applications using The National Map. Total costs and benefits of The National Map were based on the projected implementation time, development and maintenance costs, rates of data inclusion and integration, expected usage levels over time, and a benefits estimation model. However, the lack of data to populate the economic model and the lack of literature on the value of spatial data in real-world applications resulted in an uncertain cause-effect relationship *"because [. . .] a full accounting of the likely costs and benefits was not feasible"* (ibid. 14).

The studies by Giff and Coleman (2003) and Masser (2003) can also be considered as SDI learning evaluations, although the evaluation "format" was "comparative case studies" instead of a computational simulation of a complex reality. These studies identified appropriate role models (countries at similar levels of development) and extracted lessons from their experiences. For the Canadian study by Giff and Coleman (2003), the role models were Germany, the Netherlands, and France. The lessons learned included the importance of sustained political support and a strong coordinating body, as well as the advantages of a phased implementation to demonstrate benefits. For the European study by Masser (2003), the role models were Canada, Australia, and the United States. Lessons learned included the importance of industry associations and of state-level initiatives for SDI development in these countries. In both cases, the lessons learned diminished some of the uncertainty related to cause and effect.

The workshop convened by the Federal Geographic Data Committee in Kansas City can also be considered a SDI learning evaluation (Weiss 1998). The workshop's explicit objective was to answer the question, *"How do we know how we are doing at building the NSDI?",* a classical instance of high uncertainty related to cause and effect. Instead of a computational model, the workshop format allowed participants to contribute, listen, and think collaboratively from their distinct perspectives, identify indicators for success, clarify benefits, draft approaches to measure progress, examine critical issues, and prioritize action steps.

SDI sense-making evaluation. The first-ever global SDI survey conducted by Onsrud (1998) may be considered exemplary for SDI sense-making evaluation. It was spurned by the recognition that knowledge was lacking of the approaches pursued in each nation as well as of the elements and characteristics that appear to be foundational and common in most efforts. The purpose of the evaluation was to decrease this uncertainty and to articulate common approaches and characteristics shared across as many nations as possible globally. The method consisted of soliciting official and unofficial responses from individuals *within* each nation to provide a platform for sharing differing views and for building consensus as to SDI scope, nature, and extent—in other words, consensus related to a minimum set of SDI objectives. The cause-effect relationship was one of high certainty, for the intent was to encourage library-like widespread sharing of spatial data.

Experimental methods such as prototyping and modeling can also be considered instruments of sense-making evaluations. For example, Kuhn et al. (2000), in examining the technical feasibility of the SDI reference model of North Rhine–Westphalia in Germany, recognized that a key issue was to ensure its acceptance through consensus building. The authors initiated a dialogue by suggesting procedures to ensure consensus processes *within the SDI project,* with project partners expected to give their feedback to the rules and specifications of the reference model within three weeks after the dissemination of each new version of the reference model. They also suggested consensus-building processes *within the GI market* of North Rhine–Westphalia. Giff (2005) used simulation modeling to evaluate SDI funding models over time and to observe the models' response to changes in key variables operating within the specific implementation environment.

SDI exploratory evaluation. The interpretive study by Rodriguez (2005) can be considered exemplary of exploratory SDI evaluation. Rodriguez's structured theoretical tool for the assessment of SDI initiatives is based on a participative, formative, transformative process that empowers all stakeholders involved in the social construction of spatial data infrastructures while at the same time changing the schemata of stakeholders and the assumptions that influence them. His conceptual framework examines data systems–centered efficiency and services-centered effectiveness, but above all it takes into account the dynamic interplay of social contexts with the technical implementation process of geographic information infrastructures.

In assessing efficiency, Rodriguez's framework accepts that performance monitoring and quality improvement of data and systems are essential components of SDI evaluation, under the condition that suitable needs, expectations, and objectives are defined in regard to each particular context. In assessing effectiveness, it recognizes the importance of evaluating the SDI's potential for producing and delivering the intended geospatial products and services to users, according to their interests, capabilities, and capacities. In proposing understanding of cultural and sociopolitical interactions surrounding SDI implementation as part of the evaluation, Rodriguez's framework anticipates that stakeholders will be conflictive and critical, but also sees conflict as an opportunity to reconcile interests and generate more appropriate SDI ideas, concepts, applications, and services to citizens.

In summary, the focus of SDI evaluation has broadened to include data, services, SDI management issues, as well as some governance issues. From the point of view of epistemology, there is a shift from positivist to interpretive evaluation. However, a holistic governance-centric SDI evaluation perspective is still missing. To tackle the question, *"Which are appropriate SDI evaluation approaches in the dynamic and volatile environment of e-governance?"*, we now turn our attention to e-governance, a new and turbulent field, still in the phase of finding and refining its research agenda and its accepted standards and methods (Scholl 2005).

Governance and E-governance

Governance at any level—urban, regional, or national—can be conceptualized as "the interactions between actors in three distinct but interrelated spheres: the political, the public administration, and the society spheres" (Grönlund 2004, 2005). Figure 1 illustrates Grönlund's democratic governance model. The three spheres are represented by circles indicating domains of control. Arrows indicate influence. Intersections of circles indicate "transaction zones" where control is negotiated by e.g., lobbyists and media on the left-hand side, commercial service deliverers on the right-hand side, and government boards and committees on the top side. "Governance" (electronic or not) concerns all three spheres, while "government" (electronic or not) can be taken to mean either just the administrative or the political and administrative in combination.

When governance becomes e-governance, in other words, when the full range of government activities—internal processes, policy development and decision making, and services to citizens—are made available electronically, then the domains of control and the transaction zones may change dramatically (Margetts and Dunleavy 2002). Universalist scenarios of governance transformation through IT mark two extremes, the hypermodernist and the antimodernist (Margetts 2003). The hypermodernists argue that the electronic revolution will take government to new levels of rationality, bring a new civilization peopled by information workers in intelligent buildings full of electronic offices organized in networks rather than formal hierarchies. The antimodernists concur with the hypermodernists' view of the transformative role of technology for governance but emphasize the malign consequences, with technology becoming an instrument of social control (ibid.).

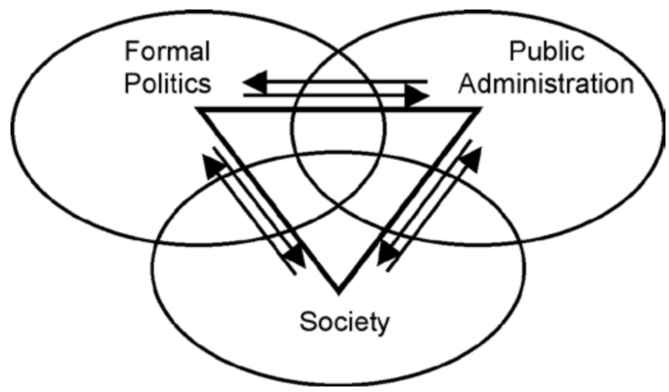

Figure 1. Grönlund's model for a governance system (2004, 2005)

E-governance research goes back at least to the 1970s (Danzinger and Andersen 2002), with the older literature concerned mainly with IS implementation within government, while more recent studies are concerned with external use, a problematic trend because of its excessive emphasis on electronic services to citizens (Grönlund 2004, Petricek et al. 2006, Zouridis and Thaens 2005). However, while research on IS implementation in commercial organizations has produced many theories (e.g., Avgerou 2000a), research related to the implications of IS implementation in government organization has fallen short of furnishing full-blown, generalizable theories. For example, the editors of the influential handbook *Public Administration in the Information Age* claim under the slightly alarming heading "Faltering Foundations" that despite decades of scholarly attention to the implications of informatization in government, scholars are still *"both empirically and theoretically 'challenged'"* (van de Donk and Snellen 1998, 14).

Empirically, e-governance research has focused mainly on individual government organizations and specifically on the impacts of IT on the capabilities of single government units. The analysis by Danzinger and Andersen (2002) of empirical research reported in more than 1,000 issues of research journals, published between 1987 and 2000, reveals a high concentration on single government units, mostly at the local administrative level. In terms of impacts of IT use in government, the study concludes that *"the clearest positive impacts generated by IT on* *public administration are in the areas of efficiency and productivity of government performance, in both internal and external (service) functions [while] negative impacts from IT are reported in such areas as citizens' private and legal spheres, citizens' interaction with government, and public employees' work environment and power relationships."* (Ibid., 617)

Theoretically, e-governance research is fraught with dilemmas and ambiguities. Public administration scholars use the conceptual lens of "informatization of public administration" to study the shifts within the administration and political spheres as well as their changing position vis-à-vis the societal sphere of governance. Van de Donk and Snellen (1998) argue that the Information Age is leading to an erosion of the system of "checks and balances" between the powers of the state, between the layers of government, and within the authorities of public administration that has traditionally served as a guarantee of civil liberties (ibid.). Zouridis and Thaens (2005) study the "locus" and "focus" of governance to understand the control shifts between the three spheres brought about by e-governance.

With respect to "locus," Zouridis and Thaens find e-governance to concentrate mainly on the operational level of public administration, as a result of the emphasis on citizens as consumers of the products and services of public administration. According to these authors, e-governance initiatives give little attention to the executive and strategic parts of public organizations. In the policy process, e-governance appears to be primarily concerned with policy implementation and not in agenda setting and formulation of policy. In the sphere of politics, e-governance is used to support democratic supervision and representation and has little affinity with propagation and consideration of ideas and political decision making (Table 4).

With respect to "focus" of e-governance, Zouridis and Thaens find initiatives in Western liberal democracies to be primarily contributing to the economic and professional rationality of public administration, with political and legal rationality largely ignored (ibid.). They come to the conclusion that the "locus" and "focus" of e-governance in liberal Western democracies is not only limited but also slanted towards increasing the influence of the public administration sphere.

In developing countries, the situation is even more uncertain. Heeks (2001) estimates that e-governance projects are 35 percent total failures, 50 percent partial failures, and 15 percent successes. He attributes failure to the gap between "hard rational design" and "soft political realities" caused by the three-way association of IT, universalist modernization, and Western rationalism. Avgerou (2000b) similarly argues that universalist visions of economic and institutional development accompanying efforts to promote the diffusion of technology downplay the path dependence and historical contingency of the development process and frustrate efforts to make sense of locally meaningful ways of accommodating information technology in socieconomic activities.

The empirical and theoretical challenges in e-governance research in liberal Western contexts, reported by Margetts (2003), Scholl (2005), Zouridis and Thaens (2005) among others, suggest that a pragmatic research approach is understanding of e-governance on the ground, in specific institutional settings, while acknowledging the path dependency and historical contingency of trajectories towards e-governance, especially in developing-country contexts, where failures by far outnumber successes. In the next section, we outline how geo-information infrastructures underpinning e-governance could be conceived and evaluated in the light of these challenges.

TOWARDS A GOVERNANCE-CENTRIC SDI EVALUATION

The taxonomy of SDI evaluation approaches in the previous section shows that SDI evaluation research has matured in a number of ways. Firstly, different evaluation orientations—with the purpose to either control, or experiment, or develop consensus, or to explore—have been developed, depending on the perceived certainty as to the objectives and the cause-effect relationship of SDI investments. Secondly, several evaluation instruments have been deployed, ranging from questionnaires to comparative case studies to prototyping and simulation to the use of theoretical grounding, and, most recently, to theory generation. Thirdly, SDI evaluation has moved from a data-centric to a service-centric perspective and is also increasingly concerned with management and governance issues. Finally, a paradigm shift has taken place in the literature, from positivism and mainly quantitative tools towards interpretivism and mainly qualitative instruments (Rodriguez 2005).

Governance	Political Sphere	Public Admin. Sphere	Society Sphere
Locus	Policy process (agenda setting, policy formulation, political decision making) *Democratic supervision* *Representation*	Policy process *(policy implementation, managerial control)* Executive and strategic level *Operational level*	Citizens as rulers (voters and participators in policy processes) *Citizens as ruled* (subject to authority, consumers of services)
Focus	Political rationality	*Economic rationality* *Functional rationality* Legal rationality	Individual or community welfare and emancipation

Table 4. The locus and focus of governance adapted from Zouridis and Thaens (2005) and Grönlund (2005). Italics are used to highlight those locus and focus that are transformed by e-governance.

The question now can be raised as to *"Which are appropriate SDI evaluation approaches in the dynamic and volatile environment of e-governance?"* In the turbulent environment of e-governance, uncertainty with respect to the implications of making the full range of government activities made available electronically is the only certainty. Consequently, the obvious choice of approach is "exploratory evaluation," at least in the first instance, that is, when we are concerned with understanding the totality of implications of the transition from governance to e-governance. With decreasing uncertainty in both dimensions, other evaluation orientations may become increasingly useful. For instance, when the evaluation scope is limited to interactions between the public administration and society spheres, and the focus is geo-services to citizens (as consumers), a control evaluation approach may be warranted. When the evaluation scope is limited to interactions between the political and society spheres and the focus is citizen (as rulers) participation in territorial planning, a sense-making evaluation may be appropriate.

Exploratory evaluation is more appropriate for understanding *holistically* existing e-governance arrangements and for cultivating an e-governance geo-information infrastructure in a specific institutional setting. Grönlund's (2004, 2005) conceptual framework suggests that e-governance information infrastructures may achieve long-term success when they sufficiently well reconcile the rationalities and interests of stakeholders in the three spheres of a governance system, shown in Figure 1. In this paper, we shall only illustrate the meaning of reconciliation of rationalities and interests by means of an exemplary e-governance geo-information infrastructure initiative, the Bhoomi land-records information infrastructure in India.

The Bhoomi (meaning *land*) land-records infrastructure was implemented in the southern state of Karnataka in India, and was launched in all districts of the state in 2001. By October of 2004, more than 22 million farmers had accessed Bhoomi since its inception (De' 2005). Bhoomi aimed at digitizing land records providing ownership information required by individual farmers for a variety of reasons, for example, such as to make loan applications to banks or to obtain an electricity connection. Before these records were digitized and computerized, the ownership certificates had to be obtained from the local patwari, a junior official in the land-records department located at the subdistrict level. In addition, these records were not regularly updated (such as incorporating transfer/sale deeds into the existing records). Copies of these records can now be obtained on payment of about 30 cents (U.S.), and without long waiting periods or the need to make several visits, and also "unofficial payments" to the patwari. Bhoomi is an exemplary land-records infrastructure that caters to a massive societal need. It has been deemed so successful that the state of Delhi has decided to replicate the initiative.

Nevertheless, a few years after its inception and use, Bhoomi can be seen to exhibit the malaise afflicting all large infrastructural systems, such as the power of "installed base," conflicting stakeholder interests, and the difficulty of second-guessing the final user behavior, which may eventually cause the infrastructure to "drift" (Ciborra and Associates 2000). Rahul De's (2005) nuanced reading of conflicting interests of politicoadministrative and societal stakeholders of the Bhoomi land-records infrastructure helps understand the (partial) resistance to Bhoomi as conflicts of interests and rationalities among stakeholders of the infrastructure. For efficiency reasons, politicoadministrative stakeholders of Bhoomi favored a single format for land records in one language, while farmers prefer multiple languages and formats, including *all* the data of the analog records that were suppressed during computerization. For effectiveness reasons, the politicoadministrative stakeholders of Bhoomi decided not to include cadastral maps in the digitized land records, arguing that the highly time-consuming activity of computerizing cadastral maps would have delayed the entire computerization process. Farmers resented the exclusion of cadastral maps, arguing that their inclusion would have made transparent the huge inequities in land tenure that had cropped up ever since Karnataka had undergone the last official land survey in 1978. For transparency reasons, politicoadministrative stakeholders favored the open availability of land records to all, while the farmers preferred privacy of land records to avoid becoming targets of land sharks. These conflicts resulted in cases now being filed in court (ibid., 34).

From this illustrative example, it appears that the long-term success of e-governance geo-information infrastructures rests on two premises:

- understanding the rationalities and modes of operation in all three spheres, formal politics, administration, and society, in a specific political, administrative, sociocultural-historical context;
- cultivating and scaling up existing geo-information infrastructures that best and most constructively reconcile diverse rationalities and interests in the transaction zones of governance systems, where control is negotiated.

Exploratory, interpretive evaluation of e-governance geo-information infrastructures should encompass primarily the degree of convergence of rationalities, interests, and modes of operation achieved among different spheres of governance. In a second step, evaluation might attempt to reflect "good governance" outcomes, such as subsidiarity, equity, efficiency, transparency and accountability, civic engagement and citizenship, security, etc. Exploratory, governance-centric SDI evaluation would involve understanding through in-depth case studies and ethnographies the interwoven dynamic relationship over time between the politicoadministrative, sociocultural, historical context and the technical implementation, through interpretation of the meanings and actions of participants and stakeholders. By understanding how the infrastructure came to be what it is now and how it is incrementally assuming infrastructural characteristics and becoming an open and shared resource will allow us to devise cultivation strategies that are context-specific and, thus, potentially more successful (Georgiadou et al. 2005).

CONCLUSION

In this article, we presented a taxonomy of SDI evaluation orientations to date and argued for the need to pay more attention to conducting exploratory evaluation of SDI implementation in specific institutional contexts, based on the premises of an interpretive epistemology and methods. We argued that such a shift is warranted with SDI now broadly understood as the geo-IT realm of the turbulent field of e-governance. We suggest that the long-term success of geo-information infrastructures hinges on cultivating and scaling up existing initiatives with the purpose to constructively reconcile diverse rationalities and interests in the transaction zones of governance systems, where control between spheres is negotiated. We also suggest that exploratory evaluation geo-information infrastructures should encompass the degree of convergence of rationalities, interests, and modes of operation achieved among different spheres of governance.

For further research, we propose conducting longitudinal, interpretive, in-depth case studies, with the purpose to enrich the theory and practice of exploratory SDI evaluation. Such research should focus on governance-centric SDI evaluation, especially in so-called developing countries. The questions as to how to establish interdisciplinary teams to conduct such research, what kind of longitudinal designs are appropriate to study and evaluate the dynamics of SDI implementation, and how to operationalize an interpretive research philosophy in practical terms to conduct empirical SDI evaluation research are all areas for further exploration.

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Statistical Methods for Spatial Data Analysis

Oliver Schabenberger and Carol A. Gotway (Chapman & Hall/CRC Press) 2005, 488 pages. ISBN 1-58488-322-7. Hard cover only.

Statistical Methods for Spatial Data Analysis offers plenty of information for the analysis of spatial data in a variety of disciplines. It is clearly written and well organized. The chapters are highly topical and come at a time when the literature on statistical methods for spatial data analysis is steadily growing. Interesting and relevant to the readership of the *URISA Journal,* this book is a valuable resource for educators, students, geographic information system (GIS) practitioners, and spatial scientists from varying disciplines.

The aim of the book is ambitious: comprehensive and illustrative compilation of the basic statistical theory and methods for spatial data analysis. Few books on the subject of statistical methods for spatial data analysis describe the methods in a thorough yet accessible manner. This text stands out because of its comprehensive coverage of a wide range of statistical methods and spatial analysis techniques.

One of the book's main strengths is the clear organization of its chapters. Each chapter starts with an explanation of the theory with well-chosen examples explaining the statistical method. Most of the examples use simplified real-world datasets and sometimes hypothetical datasets with a few exceptions. For example, the woodpecker data, lightning-strikes data, rainfall data, and low-birth-weight data represent a variety of disciplines, which makes the book very useful for scientists across disciplines. Necessary equations are provided for each method with a wealth of informative figures, which contribute substantially to developing a better understanding of the methods described. As could be expected for a book of this nature, it includes a fair amount of mathematics. Each chapter ends with problems that encourage the readers/students to apply the statistical methods described to a specific problem.

The book contains nine chapters. The introductory chapter provides the needed background on the characteristics and types of spatial data, and the nature of spatial processes and patterns such as autocorrelation functions and the effects of autocorrelation on statistical inference. Chapter 2 describes the theoretical framework of random fields necessary for subsequent chapters, particularly Chapters 4 and 5. Chapter 3 covers point-pattern analysis with a well-named title, "Mapped Point Patterns." The authors should be congratulated on doing such a solid job of including the relevant spatial processes and techniques applicable to point-pattern analysis. Chapter 4 primarily deals with semivariogram, estimation, and modeling of the covariance function. Chapter 5 covers spatial prediction and kriging. In this chapter, the authors elaborate on general details of the spatial prediction problem and give an extensive overview of kriging, with comparisons such as local versus global kriging. They also cover trend surface models with illustrations. Chapter 6 is a comprehensive coverage of spatial regression models, beginning with linear models with uncorrelated errors and ending with a succinct discussion of Bayesian hierarchical models for spatial data. Chapter 7 describes simulation of random fields, followed by Chapter 8 on nonstationary covariance. The final chapter on spatiotemporal processes primarily deals with separable and nonseparable covariance functions and spatiotemporal point processes.

Each of the various statistical methods is described in considerable depth. The book's main strength is that it describes basic statistical concepts for spatial data analysis and explains them and their relevance clearly in a single volume in a consistent manner. Most spatial analysis textbooks do not cover the relevant statistical concepts. This book demonstrates that spatial analysis requires a consistent recognition of basic statistical theory and methods for spatial data analysis. Including simulation techniques as one solid chapter in the book is a very good addition for this subject is often overlooked in most other textbooks on spatial statistics. The subject index of the book serves as a glossary of spatial methods in alphabetical order.

While applying the statistical methods to a specific problem at the end of each chapter is a very meaningful and helpful way of better understanding the concepts, especially when worked into course material, unfortunately, having no answer key makes it harder for readers, when they are not using the book in a class setting. Maybe the answer key could be provided in the CRC Press Web Site along with the other materials in the book.

A shortcoming of the book is that other than SAS/STAT and S+ software, there is little reference made to software that might be used to carry out the spatial statistics described. When used in a course setting, this would be the task of the instructor, but for others using the book as a reference, it will take considerable effort to identify how GIS and related software has implemented the various techniques. Although most commercial GIS software does not include many of the statistical techniques referred to in the text, the use of a statistical software package is pretty much a requirement to carry out many of the techniques covered in the book. This is not really a weakness of the book itself, but simply the reality of how most spatial statistics software has been developed on and with a GIS platform. But it is promising and encouraging that the material in the book will be supplemented with the CRC Press Web site, which will provide many of the datasets used in the text and the software codes to implement the principal methods described.

Although the GIS may not be absolutely necessary for spatial analysis and spatial statistics, it can facilitate such an analysis and moreover can provide insights that might otherwise be missed. The way this book is structured, it misses the issues associated with mathematical modeling and GIS and research oriented towards the linkages between spatial analysis and GIS. A chapter just dedicated to the integration of spatial analysis and GIS could stimulate the interest of readers in quantitative spatial science, particularly exploratory and visual types of analysis. This would diverge from the main goal of the book, which is covering the common spatial theories and statistical methods in detail. But it could definitely help the GIS-user readers to strengthen their spatial analysis skills by using the concepts explained in this book.

This book will be most useful as a textbook for graduate spatial statistics courses. I highly recommend it for educators. It can be used as a textbook in a variety of disciplines. Schabenberger and Gotway are to be congratulated on bringing together a valuable addition to the spatial statistics and spatial analysis literature. Production by publishers Chapman & Hall/CRC Press is to a high standard, with an attractive cover and a high quality of print. No doubt, this book will make statistical methods for spatial data analysis useful for scientists across many disciplines.

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