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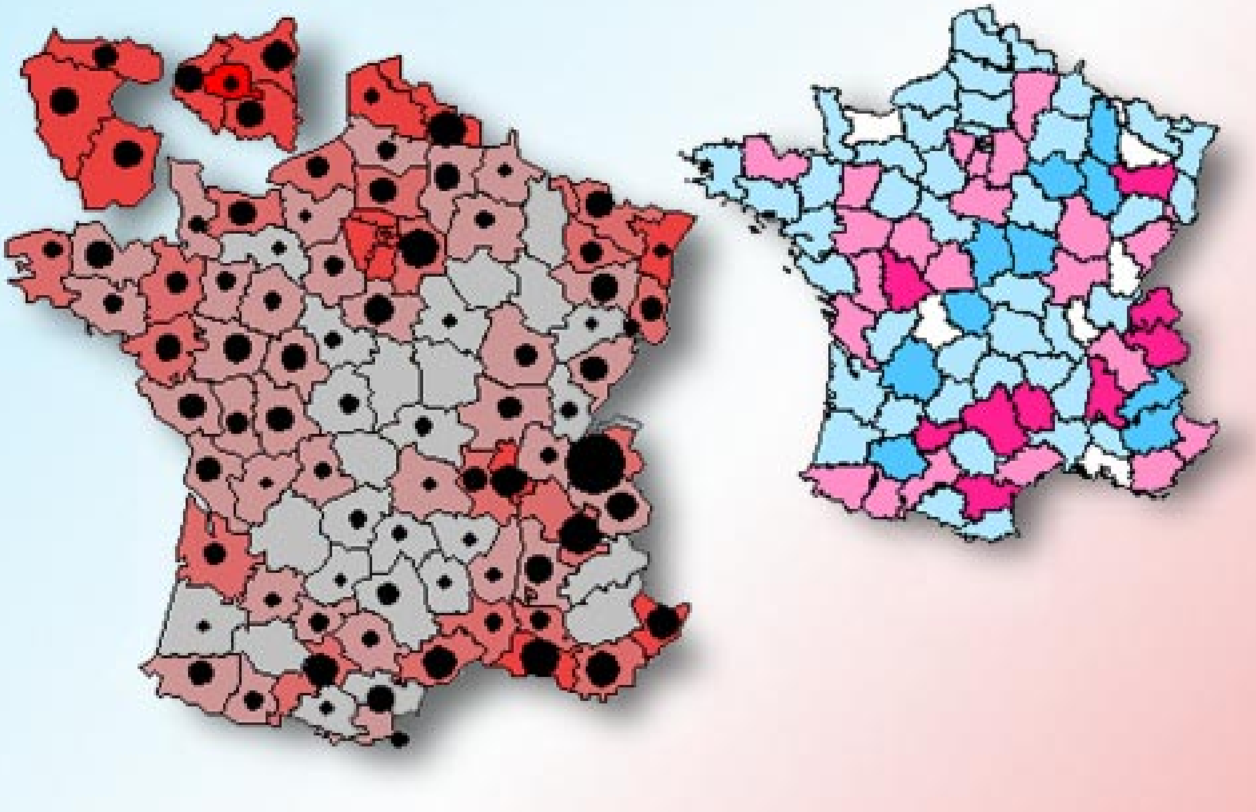
URISA®

Journal of the Urban and Regional Information Systems Association



> **"A common language (i.e. a negotiated spatial and conceptual framework) between experts and elected representatives is necessary."**
>
> **—*Roche & Humeau***

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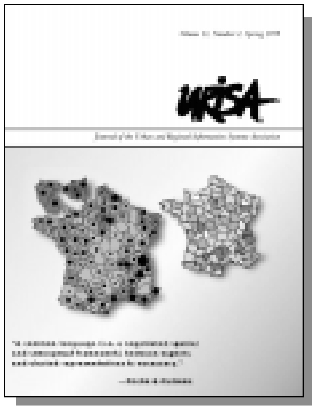

On the Cover

These GIS representations indicate the growth and development of geographic information systems at the municipal level in France. Regional GIS projects in France have allowed some the poorest municipalities to learn about new technology and new gave new opportunities for cooperative efforts in meeting regional planning mandates. For more information on this application of GIS, see the accompanying article on page 5.

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EDITORIAL: New Policies Advanced

As Editor-in-Chief of the *URISA Journal*, I am pleased to be implementing new policies that are designed to further the advancement of knowledge and science. The new plan for the *URISA Journal* formulated two years ago is being advanced with sweeping policy changes in submission guidelines, the peer review process, and copyright privileges.

A distinguishing factor now setting apart the *URISA Journal* from most other academic journals is that authors will no longer be required to give up exclusive rights to their intellectual work to the publisher. Under the new policy, authors publishing in the *URISA Journal* retain full, but non-exclusive, rights to their articles. It requires that full credit for first publication in the *URISA Journal* is provided in any subsequent electronic or print publications.

URISA's web site (www.urisa.org) has a full description of the copyright and submission guidelines. The *URISA Journal* will now dedicate itself entirely to peer-reviewed works. All articles must be submitted in electronic form; however, the peer review process will not begin until the signed copyright agreement and a single paper copy of the article are received by URISA Headquarters in Park Ridge, Illinois.

In addition to the policy changes, the *URISA Journal* is expanding to three publications in 1999 and to a quarterly publication in 2000. This increase in publications, and the exclusive use of peer reviewed works, will provide additional space so that a greater number of papers can be accepted and published in a timely manner.

Academic scholars and scientists need the freedom to make their ideas, concepts, data, and research results freely and thoroughly accessible through every means possible in order to allow open discussion, critique, and intellectual exchange. The *URISA Journal* is devoted to promoting the advancement of knowledge and science.

Harlan Onsrud

In this Issue…

Five refereed articles are presented in the Spring 1999 issue.

Roche and **Humeau** give three examples of multi-partnership GIS projects formed by small municipalities in response to French State mandates for regional development.

Kellogg describes the data management capacity issues that arise for a community based development organization in inner-city Cleveland.

Agumya and **Hunter** propose using risk based assessment of spatial data as an alternative to standards based assessment, illustrating the process with an example of emergency response planning in a flood zone.

Flewelling discusses the problems arising in comparisons of spatial datasets, presenting analysis of storage and retrieval of individual items in multiple digital spatial datasets by distinguishing the concepts of identity, equivalence, and similarity.

Nedovic-Budic and **Pinto** review the literature on management of the interorganziational GIS and focus on the benefits of coordinating GIS developments and database sharing

GIS Development and Planning Collaboration: a Few Examples from France

Stéphane Roche & Jean-Baptiste Humeau

Abstract: *This paper deals with the characteristics of French territorial organization and problems arising from the decentralization of power to municipal level. Three case studies illustrate how the implementation of partnership geographic information systems (GIS) projects can contribute to inter-municipal cooperation in regional administration.*

Key-words: *France, decentralization, regional planning, partnership project, local government.*

Introduction

In France, public action to promote local economic development is linked to cooperation between communes (municipalities - the basic administrative unit). Recent laws on territorial decentralization (1982) and planning (1992) clearly establish the decision-making responsibilities of municipal authorities regarding land administration. But the size of the municipalities (90 % of the 36,000 French municipalities have fewer than 10,000 inhabitants), a legacy of the religious spatial structures of the 18th century (the parishes), is too small to permit efficient regional planning (Table 1). For a long time, public authorities have attempted to change this situation. Recent decades have seen unsuccessful top-down attempts to fuse small municipalities. Voluntary cooperation between municipalities through the creation of inter-municipal syndicates dates back to the end of the 19th century. The "Communautés de communes", an inter-municipal structure encouraged by the State since 1992, reflect early State attempts to modify municipal structures. How can the relative success of this central State initiative be explained ?

People's historical ties to their area remain too great to allow modification of communal borders. However recent demographic data shows that the context of this problem is evolving with increasing popular demand for more and more costly public infrastructure. As the rural population gets smaller in some areas, many rural municipalities are unable to raise enough fiscal resources for basic public investment. Peri-urban development in belts of 10 - 40 kms around most towns emphasizes the importance of mid-scale territorial management. Intermunicipal cooperation beyond the urban centre is vital in establishing networks of collective infrastructure. In France, territorial reorganization is a much-discussed issue. Rapid geographical change in the last three or four decades, and present constraints on public finances, have focused attention on the necessity for territorial administrative structures that allow for optimum efficiency.

The present development and spreading of geographical information technologies (Map 1), especially GIS, and

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Dr. Jean-Baptiste Humeau is currently Professor in the Geography Department and Head of the Social and Human Geography Laboratory (CARTA) of the University of Angers. He holds undergraduate and graduate degrees in Geography from the University of Angers, and a Ph.D. from the University of Caen (France). Dr. Humeau has published widely in the field of social geography and land planning policies. Publications include three books, more than 10 book chapters and 30 refereed journal papers. He has led many research initiatives, funded by several french ministries and European organizations, in France and Eastern Europe related to land reform, urban and rural development policies, and regional planning.

Table 1: Characteristics of a few European countries

	Number of municipalities	**Total surface** (km2)	**Average size of municipalities** (km2)	**Density** (Inhabitants/km2)
USA	60,000	9,364,000	156	28
ITALY	8,100	301,000	37	189
PORTUGAL	305	92,000	302	109
FRANCE	36,494	594,192	16	100
West GERMANY	8,500	284,577	33	244
BELGIUM	2,500	30,521	12	324
The NETHERLANDS	650	33,938	52	427
LUXEMBOURG	175	2,586	15	142

their local implementation appear to offer small municipalities new opportunities for collaboration. Although isolated use of such tools in small municipalities remains difficult, collective use by groups of municipalities is feasible, provided certain conditions are met. Certain case studies already show that GIS can act as a catalyst in bringing municipalities together around a common project. Firstly, an inter-municipal approach to GIS use allows the poorest municipalities to join the present trend towards geomatics. Secondly, an inter-municipal GIS project provides an indispensable common focus for successful inter-municipal cooperation. Thirdly, a GIS project provides municipalities not only with efficient means to fullfil their mandate in regional planning but also a common conceptual basis for the development of joint planning strategies.

The main aim of this paper is to show, through a few examples of GIS projects, how and to what extent a multi-partner GIS project venture can act as a catalyst in inter-municipal cooperation and help smaller municipalities to deal with their newly decentralized powers. Indirectly, this paper also addresses how the use of a GIS, and the geographical information it provides, can facilitate thinking and dialogue in the field of territorial administration.

This research investigates areas that have already been studied to a greater or lesser extent. In particular, it is strongly related to the question of the human and social implications of GIS (the main theme of Initiative 19 of the National Center for Geographic Information and Analysis - NCGIA) (Harris and Weiner 1996). Other authors have also shown the relevance of such questions (see for just a few examples: Weber 1991; Campbell and Masser 1995; Pickels 1995; Pornon and al. 1995; Masser and al. 1996; Roche 1996; Roche and al. 1996; Roche 1997a). GIS projects are social constructions, both modified by local users and modifying the local context (Chrisman 1997; Roche 1997b). Our study is particularly inspired by Chrisman who underlines the importance of re-situating the study of GIS (as well as their implementation) in their cultural and historical context in order to improve understanding of their use and potential role.

Our paper starts with a synthesis of French territorial organization. We then focus on the new challenges and difficulties these policies have created, particularly regarding smaller municipalities. We conclude with three case studies that illustrate the benefits of GIS in promoting collaboration in regional planning.

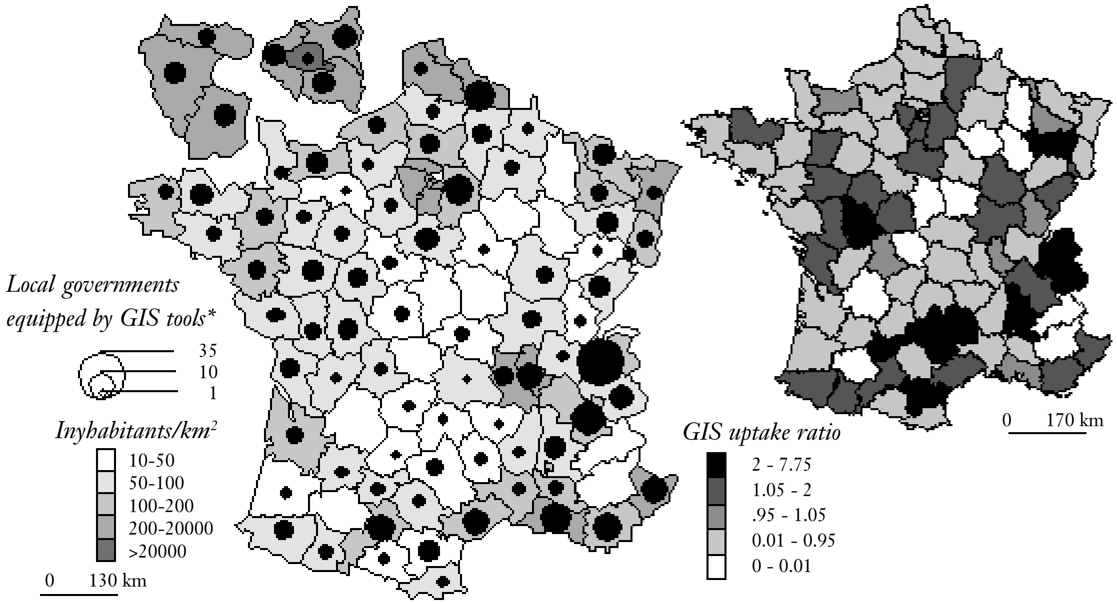
French Territorial Organization

Levels of Territorial Power

Since the Territorial Decentralization Law (1982), decision-making at the local level has undergone profound changes. The responsibilities of the French national State, renowned for its centralization of power (its "Jacobinism" in reference to the political trend of the Revolution and the Empire periods), have been decentralized to four levels of territorial administration (Gruber 1992): commune (municipality); municipal groupings such as the "Communauté de communes" and the "Syndicats" or "districts intercommunaux"; "Département" (the county); and "Région". They all have statutory responsibilities, tax-raising powers and are accountable to regulatory bodies such as the regional audit office.

The municipality is endowed with major urban planning responsibilities. The "Plan d'occupation des sols" (POS or Land Use Plan) has become an essential planning tool for local authorities. Municipal authorities (with the exception of small rural municipalities which remain under the administrative trusteeship of the State) draw up a POS map defining every plot of land and its permitted use for residential building, new business activities, cultural and social facilities, roads and major collective infrastructure. Public infrastructure must be planned in accordance with this legally binding document. The POS is both a regional planning tool for technicians and a political tool defining the

Map 1: *Spatial distribution of GIS tools by "département"*



**municipalities and intermunicipal structures*

Sources: Observatoire Geomatique 1996, IETI & RGP, INSEE, 1900

The "GIS uptake ratio" = R1/R2

R1 = number of local government structures equipped with GIS in a given department, divided by the total number of local government structures equipped with GIS in France.
R2 = the population of the same department divided by the total population in France.

The "départments" where local government structures are the least equipped with GIS correlate with those with the lowest population density (south-west / north-east axis). On the other hand, the south_east, north-west and Paris regions are much better equipped. (Roche and Humeau 1998)

major development orientations of a municipality as decided by its elected representatives.

The Territorial Decentralization Law also devolved responsibility for the management of primary school infrastructure and social and cultural facilities to the municipal level, as well as various measures in favour of economic development. This represents a revival of an old tradition in French municipal affairs: the responsibility of the municipality to satisfy local needs. This interpretation of the municipality's obligations raises problems in a State which recognizes the primacy of private initiative, notably in economic matters. In a difficult economic environment, particularly regarding employment, local authorities are faced with considerable demands on limited resources.

The need for municipalities to be competent in an increasingly wide range of areas has led elected representatives to seek more efficient forms of inter-municipal cooperation. This is not a totally new idea; in the 1950s, inter-municipal syndicates were responsible for the efficient development of electricity distribution networks, and elected representatives have since attempted to multiply inter-municipal structures that allow more efficient management than that attainable at the individual municipal level. A good example is the "Schéma directeur d'aménagement urbain" (SDAU - Guidelines for Urban Planning). In the case of big agglomerations (the Angers SDAU involves 54 municipalities, that of Nantes 65 communes...), the SDAU brings together the elected representatives of a large area to assess urban growth and agree guidelines for each municipal POS. This kind of inter-municipal cooperation is increasingly necessary; the 36,000 French municipalities have become too small given the big increase in mobility (residential, professional, social, cultural...) of urban and rural populations (Beteille 1995). The 1992 law on Territorial Planning (1992) recommends and financially encourages modern inter-municipal structures such as the "Communautés de communes" and "Pays".

The "Communautés de communes" are a flexible and evolving form of inter-municipal structure. They have compulsory responsibilities (such as regional planning), with optional responsibilities that can be enlarged over time according to the will of their elected representatives (Baudelle 1995). The "Pays" are bigger structures than the "Communautés de communes". Their aims are different.

The west of France has a long experience of pays (Map 2) pre-dating the recent law on territorial planning, with groups of municipalities working together to facilitate economic development. Most often, these pays were created around small towns and deliberately ignored the bigger ones which were blamed for accelerating the demographic and economic collapse of rural areas. By providing a legal basis for the constitution of pays, the law has recognized the reality on the ground, although questions remain concerning the nature and relevance of their plans for development. Moreover, it is not easy to share territory and responsibility between the "Pays" and the "Communautés de communes". Planning technicians can only have a limited point of view on such issues, which must ultimately be decided by the elected representatives of the area.

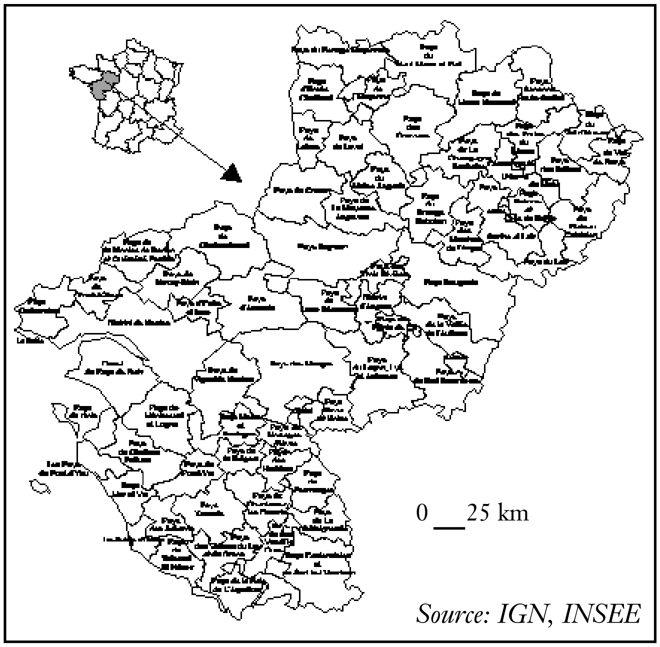
The "Département" (created during the Revolution) and the "Région" (an administrative area created in 1967) also have new regional planning powers. The "Département" is responsible for managing lower-level secondary school ("Collège") infrastructure, providing certain social services, and maintaining infrastructure for economic development (local roads, bridges and industrial estates). Similarly, the "Région" is responsible for upper-level secondary schools ("Lycées") and technical and vocational schools. Every five years a regional development plan is negotiated with the State to fix major planning priorities: major infrastructure, promotion of economic development, research, etc. A sizeable budget funded by specific regional taxes gives the "Région" considerable financial power. The "Région" also has privileged links with the European Union, receiving EU financial aid and influencing regional reform.

The Issues

The policy of regional reorganization is progressively modifying all the administrative practices of state and local government. New mechanisms allow new regional planning practices at different levels. New centres of power are emerging which are more closely in touch with local realities. However these new practices also create problems which have yet to be fully analyzed because the process of regional reorganization is incomplete.

The multiplication of levels of intervention is undoubtedly one of the most intractable obstacles. The multiplication of local administrations was identified as a potential problem at the very beginning of regional decentralization, and experience has shown this to be in some respects well founded. The overlapping of regional structures presents clear weaknesses, as in the case of the "Communautés de communes" and the "Cantons" (an administrative grouping of communes that essentially provide a constituency for the election of counsellors to the departmental council). The "Pays" is still faced with the choice of relevant borders that reflect geographical data and older administrative boundaries. Eliminating the old borders and rationalizing the number of elected representatives would have proved politically unacceptable. Nevertheless, the inefficiency of adding and superimposing spatial structures is increasingly evident (Humeau 1995). The definition of responsibilities between regional structures is based on the principle of "subsidiarity" : each regional authority identifies and implements projects at its own level and within its area of competence, using its own tax resources and sometimes also additional finances from other regional authorities. This principle is aimed at increasing the responsibility of each regional authority and shortening the time it takes for local administrations to react to the needs of the elected representatives. Relations between the different levels of regional authority are defined by the regional plan, and various co-financing agreements. The latter have become a basic rule of action for regional authorities.

***Map 2**: "Pays" in the Pays-de-Loire region*



Source: IGN, INSEE

The financial problem has become the central issue of territorial reorganization. Regional planning cannot overlook the difficult problem of fiscal resources. Small rural municipalities are presently strangled by limited fiscal receipts, though inter-municipal structures have access to greater resources. However, disparities of tax resources between municipalities, between inter-municipal structures, between "Départments" and between "Régions" do not reflect degrees of need: the greatest need in regional investment is located in the poorest areas.

The newly created regional authorities are discovering the importance of improving the spread of taxation wealth among inter-municipal authorities. The creation of «structural financial funds» for use by State representatives in the departments further indicates awareness of the limits of financing regional investment by regionally unequal tax resources. Although setting the main priorities in local and regional development remains the prerogative of the elected members of the regional authorities, projects and financing must now correspond to national and European requirements.

The importance of a multi-level approach to regional planning is being further increased by the need to integrate these new levels of territorial administration. A map is only one of the elements involved in understanding local areas; projects using various types of observation and evaluation must be able to integrate essential and variable information. A common language (i.e. a negotiated spatial and conceptual framework) between experts and elected representatives is therefore necessary (Roche & Bédard 1997). GIS tools permitting the management of socio-spatial data-bases are becoming more and more complex. The increasing number of cartographic documents makes it even more important to identify the most relevant data. The choice of which data and how to represent it has therefore become a question of power among elected representatives and technicians (Pornon 1997). A gap is appearing between those who can assimilate these GIS techniques and those who cannot (Roche 1997b). _Geographic information systems are being established by a number of regional authorities as the need for tools that organize regional information becomes increasingly obvious to both technicians and elected representatives. Development projects need this information and the ability to update data at varying scales (local, regional, national, European).

What Roles for GIS In Inter-municipal Collaboration ?

The use of geomatic technologies by French municipalities has been growing steadily since the eighties (IETI 1996). However, implementing a GIS project is a delicate operation and can be a major problem for smaller municipalities. Whilst the costs of GIS hardware and software are no longer a major impediment, the cost of data and the institutional obstacles linked with legal authorizations to purchase data - such as cadastral surveys or IGN ("Institut Géographique National": National Geographic Institute) databases - often make it a complex process. These difficulties are particularly felt in small local authorities due to the lack of technical staff to undertake such a task. In short, the three main obstacles to implementing a GIS are the following:

Most municipalities consider the cadastral survey to be the basis for implementing a GIS project. But cadastral service policy is far from helpful to small municipalities. The cadastral service will participate in the cost of digitizing and updating municipal data only if it involves a minimum number of 150 cadastral sections, way in excess of those commonly present in a single municipality (Roche 1993). This subsidy policy[1] also imposes strict standards of digitization and data structuring and the provision of equipment (hardware and software) to the cadastral service. Such demands increase the necessary financial investment and hinder the spread of GIS among small municipalities.

Secondly, the cost of all geographic data is very high in France, unlike in North America for example. The acquisition of the data needed by a municipality to implement a GIS (digitization of cadastral surveys, aerial photos, IGN numerical databases such as the databases Topo, Carto and Alti, etc.) is extremely costly (e.g. BDTopo : 400 $US / km^2 ; 6 $US / digitized cadastral parcel). It is certainly too expensive for the majority of small and medium size towns.

Finally, municipalities with fewer than 10,000 inhabitants experience specific problems that obstruct and limit the individual implementation of GIS: the lack of technical staff to support the project, operate the system, and update the data (Pornon et al 1995; Roche and Pornon 1996), and the difficulties experienced by elected councillors in understanding the equipment and its potential.

The pooling of financial and human resources appears to be the right strategy for small municipalities who want to invest in geomatics. Implementing a GIS project is easier within the framework of a "multi- partner project" that shares costs and resources. A number of problems obviously remain and new ones arise with the partnership. For a group of municipalities, such projects can present a real opportunity either to enhance and extend cooperation within an existing inter-municipal structure or to create new structures based on the common project. In all cases, it appears that implementing a GIS can provide a catalyst for municipal cooperation in land use management and planning.

This thinking is illustrated by the case studies of the GIS projects of the "District Urbain d'Angers", the "Conseil Général du Département de l'Ain", and the "Pays Yonnais" (Map 4). These three separate projects have been developed in different geographical surroundings, with varying origins, aims and participants. These different contexts and characteristics, as well as the main difficulties and future prospects of each of these projects are presented below. The potential for a new approach to cooperation in regional planning based on these experiences is also examined.

The GIS Project of the "District Urbain d'Angers"

The "District Urbain d'Angers" (DUA - Urban District of Angers) is an inter-municipal structure that provides logistical and technical support for 29 municipalities, including the town of Angers itself with about 80,000 inhabitants. The total population numbers about 200,000 (Table 2). The DUA services carry out regional management and planning operations (such as the "Plan d'Occupation des Sols", and the "Schéma Directeur d'Aménagement Urbain") on behalf of the DUA municipalities. About three years ago, the DUA started work on a GIS project.

The Angers region provides a specific context as regards the development of GIS. In 1986, the "Conseil Général de Maine-et-Loire" presented a proposal for a departmental geomatic centre aimed at providing all local participants (private sector, regional authorities, administration, etc.) with a comprehensive geographical database covering the department (Roche 1993). At the time, this proposal received little support from the municipalities concerned, especially from Angers. Was the project premature? Or was local awareness insufficient? Local politics provide some explanation for these difficulties : the municipality of Angers is left-wing whereas the Maine-et-Loire department is traditionally right-wing. More fundamentally, the proposal was a good example of what Cohen et al. (1972) calls "a solution looking for a problem". The project initiator was unable to involve the majority of the local stakeholders in the project's implementation; the process of translation never took place (see Latour 1989).

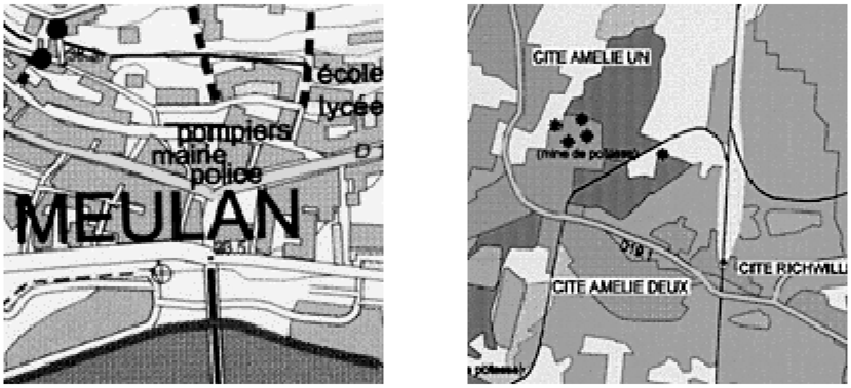
Whatever the cause, today ten years later, the departmental geomatic centre is reduced to the minimum and is exclusively used by a few departmental services. The advantages for even the smallest municipalities of purchasing a digital cadastral database have also been promoted locally by the "Ordre des Géomètres-Experts" (OGE - professional association of land surveyors). In 1993, a survey was undertaken to assess the particular needs and requirements of 13 municipalities of fewer than 10,000 inhabitants around Angers (Roche 1993). The DUA project is therefore being undertaken in a context in which the municipalities, even the smallest ones, are more or less aware of GIS; this has helped its implementation.

Instigated by the DUA urban planning service, the project's aims are to facilitate and optimize the creation, management and updating of the POS of the various DUA municipalities and of the Angers regional SDAU. The project also aims to provide the municipalities with a standard and updated database combining the cadastral survey and the IGN Topo database, with maps of the utility networks and projected development. Digitalization of the cadastral survey has been implemented in conjunction with the services of the DGI ("Direction Générale des Impôts" - General Direction of Taxation), along with the establishment of closer links with the various managers of the local utility networks.

The organization of the database should enable all the municipalities to have access to common data (cadastral survey, networks, POS, Topo database), either directly or on demand, with the updating and the management being carried out by the GIS service of the DUA. Depending on their individual level of interest, and available resources, municipalities are able to establish their own computerized access point, and to input additional information. Municipalities receive updates in disk form, except the town of Angers which is already connected to the DUA through a network. The project is proving to be very versatile for the smaller municipalities, enabling them to have access to data through the DUA in the first instance and then to invest in equipment according to their needs and budget. That project has been well received by the smaller municipalities of the DUA (the district council allocated a budget of seven million francs over two years to digitize the cadastre of it's 29 municipalities). Awareness of the technology generated by the OGE and the various surveys carried out among the small municipalities of the "Département de Maine-et-Loire" undoubtedly contributed to their positive attitude to the GIS project.

Although the project now appears to be accepted and indeed appreciated by the DUA municipalities, negotiations resulting in the digitizing and partnership agreements have not been without problems. Reaching a consensus on such

Map 3 *IGN's BDTopo and BDCarto*

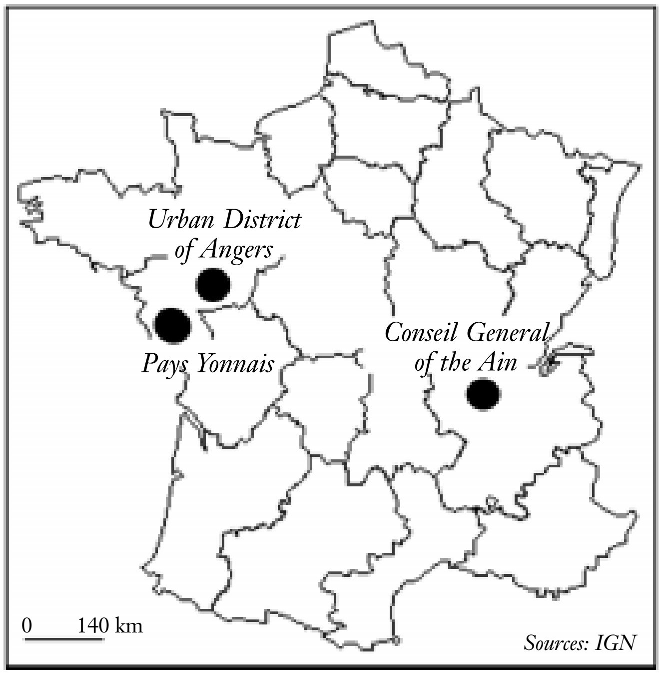


BDTOPO

BDCARTO

Source: http://www.ign.fr

***Map 4** Location of the Case Studies*



Sources: IGN

issues as the characteristics of the system and the rights of use and access to information, involved delicate negotiations between parties whose interests were not necessarily convergent (different municipalities, managers of networks, services of the DUA, cadastral services...). The main difficulty undoubtedly dwelt in the choice of an acceptable solution for smaller municipalities who, despite their short-term incapacity to invest in their own consultation equipment (desktop GIS), nevertheless had to participate in financing the database through the DUA.

In this case, GIS implementation has not led to the creation of an inter-municipal structure. However, the availability of GIS resources has allowed the technical services of the municipalities and those of the DUA to envisage new forms of collaboration. Until now, relations between the municipalities and the services of the DUA have been limited to the assemblies of elected local representatives. The introduction of GIS creates new working relations between technicians. Access to a common data-base gives them a common analytical and administrative basis. According to these participants, the introduction of a GIS is the opportunity they were awaiting to work together on something concrete and to communicate directly without going through the elected assemblies.

The GIS Project of the "Conseil Général de l'Ain"

The GIS project proposed by the "Départment de l'Ain", in the east of France (Table 2), involved the digitizing of the cadastral survey in a joint collaboration between municipalities, inter-municipal structures, decentralized State administrations and various departmental private sector organizations (Dresin 1995). The aim is to centralize information at departmental level, with administration, updating and access provided by the departmental services together with the SIEA ("Syndicat Intercommunal d'Electrification de l'Ain" : Inter-municipal syndicate for the electrification of the Ain). The main aims of the departmental GIS are twofold : to facilitate coordination between various departmental structures and to provide access to various data at various geographical levels.

For the municipalities, particularly the smallest ones, whether they are part of an inter-municipal structure or not, this approach appears interesting. The project aims to give them more autonomy in local development projects, urban planning and network administration (i.e. extra responsibilities, imposed without extra funding through decentralization), by providing them with appropriate equipment and information and technical support. Municipalities will then have access to data (generated from the departmental base to EDIGEO standard - "Echanges de Données Informatisées dans le domaine de l'information GEOgraphique" is a French standard for the exchange) via

***Table 2** Characteristics of the three case studies*

	District d'Angers	Département de l'Ain	Pays Yonnais
Total population (inhabitants)	238,000	471,000	77,338
Total surface (km2)	588	5 762	250
Average density (inhabitants/km2)	405	82	309
Number of municipalities	29	419	15
Average size of municipalities (inhab.)	8,200	1,124	5,156
Biggest municipalitie (inhab.)	146,000	40,970	48,000
Smallest municipalitie (inhab.)	94	14	393
Nb of municipalities > 10 000 inhab.	4	4	1

the telephone network. Each municipality is free to decide whether and when to invest in the appropriate access hardware. The project also aims at providing a local link between all the public sector participants, thus improving public service at the local level.

As a result of in-depth negotiations, all the aims and requirements of each authority, including the small municipalities, have been taken into consideration. But these negotiations have not been easy, particularly in regard to the rights and modes of access to the information (which is centralized in the main system administered by the department). The project had to develop a language, a syntax, a common grammar and a channel of communication so that individual partners could obtain the information according to their specific needs. This search for consensus resulted in the redefinition of certain stakeholders' involvement in the project (Latour 1989). The various participants now have access to the central database from which they can extract updated information and use it locally with the technical support of the departmental GIS service. The project has allowed participants to pool information and minimize costs. It has also allowed certain participants to exchange ideas about their respective activities.

The GIS Project of the "Pays Yonnais"

The GIS project of the "Pays Yonnais", presented by the local press (Ouest-France of 12/23/1995) as a pilot project for rural areas, is based on a contract signed by the Prefect (Government appointee representing the central State at departmental level), the "Communauté de communes" of the "Pays Yonnais" (an inter-municipal structure with fifteen small rural municipalities - (Table 2), the IGN, and many other local partners. The idea is to implement a GIS for the fifteen municipalities over two years combining the data of the various administrative entities involved in regional planning, thereby creating a system integrating a wide range of GIS data and partners. This project is not based on the digitizing of the cadastral survey, the aim being rather to create the possibility of observing the region on a global scale. The IGN and the OGE are both involved in the project, with the IGN donating its Topo and Carto databases.

The "Pays Yonnais" is a rural area located in the west of France in the department of Vendée. It is composed of small municipalities which most probably would be unable to set up a GIS on their own. The "Communautés de communes" of the "Pays Yonnais" is a young inter-municipal structure initiated by the "Vendée" Association of Mayors, which is particularly favorable to inter-municipal collaboration. Although the GIS project is not in this case a catalyst of inter-municipal collaboration, it is nevertheless perceived by the various participants as a means of promoting such links in regional planning. The project is expected to provide a common database allowing the various partners to exchange ideas on topics of local interest using data from identical sources. As such the GIS is expected to act as a "facilitator" in regional planning collaboration.

It is too early to judge the results of this project though it does show that with the support of institutional and existing inter-municipal structures, even the most unpopulated and poorest rural areas can participate in a GIS project. However, as it is not the IGN's policy to provide their databases without charge, as they did in this project, the replication of such projects would involve considerable extra costs.

These three examples are interesting for several reasons. They show that partnerships appear to be the only solution for small municipalities confronted with the lack of versatility of cadastral service policy. They also show the need for protocols that are flexible enough to allow any municipality to adapt, no matter what its size and characteristics. Finally, they show how GIS implementation can be an opportunity for wider collaboration in the field of regional planning. The three case studies also provide a few perspectives for discussion and thought for the future.

GIS Implementation as a Catalyst for Collaboration

A multi-partnership GIS project constitutes a rare opportunity for diverse participants involved in regional administration to discuss their activities, problems, and experiences. Such projects provide small municipalities with the opportunity for finding new forms of cooperation. It becomes necessary for those involved to negotiate, discuss and take into full consideration their partners' activities as well as their own (as clearly shown by F. Harvey 1997).

In some cases, GIS implementation within the framework of a multi-partner project, particularly when these partners are small municipalities, may promote further collaboration by extending areas of common interest in regional planning. It may even create new forms of collaboration as in the case of the department of "Ain". The case may also arise that such a project cannot be implemented when preliminary studies show that differences in the stakeholders' interests are too great.

The multi-partner project represents one of only a very limited number of solutions open to small municipalities wishing to have this type of technology. Some small isolated municipalities have GIS but the context of their acquisition of the technology is not replicable (for example, a mayor working in the field of GIS...). The aim of a GIS project for small municipalities is not to make them even more dependent in the field of information (as is still often the case in some partnerships) but on the contrary to give them the technological tools they need, within the framework of joint projects developed by and for all the partners.

Finally, a multi-partner GIS project provides a pool of common knowledge to all involved, which in turn can represent a common planning tool. All the partners can then base their decisions and actions on the same information and the same geographical references, undertake analyses using the same system, and communicate and exchange in a language understood by all. The advantage of such standardization is to help towards collaborative decision-making and may in the process improve the appropriateness of regional projects. But it can also cause a levelling-down of the information and thereby a dilution of the quality of the collaborative effort. Such a database doesn't however guarantee a complete collective view even if it is the result of a negotiated consensus and has been socially appropriated by local participants. Even in the worst case, this common framework helps each participant to express a point of view and make it more comprehensible to the others.

Conclusion

The aim of this paper has been to show how implementing a multi-partnership GIS project, particularly with the small municipalities, can promote collaboration in regional development and help municipalities to assume the new responsibilities the French State has vested in them.

The three case studies show that a multi-partnership GIS project can increase and promote collaboration between different municipalities. Moreover, it can provide the participants with a base of common knowledge which is absolutely vital in dealing with numerous and complex responsibilities and fields of intervention (i.e. increasingly complex legal frameworks, new environmental awareness, negotiations at multiple levels of power...). This kind of project is also the only one enabling the smaller municipalities to acquire a geographic information system. Finally, these projects answer two problems experienced by the smallest municipalities : (a) the lack of tools and resources to exercise their new powers of regional administration, and (b) their financial inability to acquire their own geomatic system even though these systems can be the answer to some of their problems.

As mentioned in the introduction, this paper reflects attempts to improve understanding of the human and social implications of new information technologies and their role in land use planning. Our study is only the first step in a larger research project. Further case studies and surveys are needed to understand the social utility of GIS projects and to identify the links between GIS construction and inter-municipal collaboration (social context).

With the pursuit of European integration and the opening of markets to world trends, more and more power lies in the hands of local institutions. Given this context, it is important to examine the methods and resources which will be used in the future. Geomatic technologies and the local societies into which they are integrated are inseparable. The role and usefulness of the former are directly related to the way the latter adopts them. The future of local societies will certainly be influenced by their ability - or otherwise - to assimilate these new technologies.

NOTES

1. This policy (convention nationale de numerisation) was modified in July 1998. Irrespective of the number of sections involved, the cadasral services now no longer participate financially in the cost of digitizing data (for further information see http://www.cnig.fr).

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From The Field: Observations On Using GIS To Develop A Neighborhood Environmental Information System For Community-Based Organizations

Wendy A. Kellogg

Abstract: *This paper describes and analyzes an application of a geographic information system (GIS) to create a profile of environmental hazards and resources in an older, inner-city neighborhood in Cleveland. The client, a community development organization, sought the profile as the basis of new organizing and community planning efforts concerning environmental quality and environmental health issues. The objective was to obtain and assemble spatially referenced environmental data existing in the public domain and map that data according to the service area of a neighborhood-based development organization. The study describes and analyzes the utility and data management capacity issues that would likely be experienced by community-based organizations using GIS in applications at the neighborhood level. This paper describes and analyzes the use of GIS to develop a profile of environmental conditions in an urban neighborhood. The project client was a community-based organization (CBO) seeking a baseline set of environmental information displayed spatially. This information would serve as a basis for community planning to develop strategies to address environmental quality concerns in the neighborhood.*[1] *We designed our project to result in a product useful for the client, to explore the issues raised in relevant literature, and to generate working hypotheses for a broader study of the use of GIS by CBOs to address environmental quality issues. The purpose of this paper is to examine the application of GIS at the neighborhood scale by and for a CBO. Through this examination we can understand better the obstacles and opportunities to make GIS a more relevant and effective technology for use by and for CBOs as GIS projects diffuse into broader society.*

Community-Based Organizations and GIS

Several reasons inhere why we should be interested in the use of GIS by community-based organizations. Community-based organizations have a long history of mobilizing resources and residents to improve the quality of life in urban neighborhoods in the United States (Silver 1985; Keating, Krumholz & Star 1996). Early community-based organizations worked to improve living conditions for immigrants living in tenements in the nineteenth century American city. These organizations included settlement houses, school cooperatives, playground advocates and child health associations (Boyer 1983; Krueckeberg 1983). In the middle twentieth century, community-based organizations gained increased in importance as federal urban poverty programs required citizen participation in community planning processes (Wilson 1991; Keating, Krumholz & Pylkas 1998). Many of these CBOs focused on social and economic aspects of community development. The role of CBOs has continued to grow in importance over the last several decades as the federal government devolved responsibility for implementation of a variety of programs to address urban problems to the local, sub-municipal and neighborhood level (Wilson 1991). City governments today often view community-based organizations as useful and even preferred vehicles for service delivery and citizen participation (Keating, Krumholz & Pylkas 1998). By 1995, there were more than 2,000 neighborhood-based community development organizations, one type of CBO, in the United States (NCCED 1995).

Community-based organizations are characterized foremost by their close working relationship with neighborhood residents and their programs to benefit neighborhood residents and address their concerns. CBOs may focus on one issue or multiple issues, including crime mitigation, housing rehabilitation, maternal and infant health care, youth programs, job training, tenant advocacy, recreational activities, small business assistance, or neighborhood planning.

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CBOs are non-profit organizations that tend to have small full time staff and depend on neighborhood volunteers for development and implementation of their programs.[2]

Existing community-based organizations and networks can play an important role regarding environmental quality concerns despite a relative lack of experience with environmental issues. CBOs often have the most intimate knowledge of community needs and assets and can better organize community members to address community concerns. Indeed, many community-based organizations today seek information about environmental hazards and assets that affect health and quality of life conditions in their service areas (Bullard & Wright 1992; Heiman 1997). In partnership with environmental advocacy organizations, CBOs might be involved in community-based knowledge production about environmental quality issues, not just knowledge consumption, a key strategy for gaining the social power needed to effect change (Gaventa 1993). A key aspect of knowledge production might include utilization of computer-based technologies, including GIS. GIS could provide a useful tool to increase the effectiveness of organizations working on the front lines of environmental problem solving.

Case Study Framework

What obstacles and opportunities arise for CBOs wishing to use GIS to help them address environmental concerns manifest at the neighborhood level? Our exploration through a field application was guided by two broad concerns that arose in previous work in the neighborhood and which we hypothesized were likely to arise for a CBO considering use of GIS for neighborhood problems: utility and capacity. What is the utility of GIS, that is, why should the organization use GIS, how relevant is GIS to its situation, how can the organization use GIS to address the neighborhood's concerns? Second, what capacities will the organization need to have in order to use GIS effectively? That is, what skills and knowledge will it need, what data will it need, what data is available and at what cost? Will the organization be able to use data effectively once has been acquired? These concerns of utility and capacity have been explored and reported in the academic and professional literature and are reviewed here (Table 1 summarizes this discussion)

Utility

Why should a CBO use GIS? Do the outputs from GIS effectively communicate information that is meaningful (Fischer 1994; King 1993) for the purposes of the CBO and to the residents it serves? Is GIS the most appropriate mapping technology (Aberley 1993) by which to analyze environmental problems as they are defined at the neighborhood scale? In what ways can GIS by used to address neighborhood environmental concerns? Does the technology serve to enhance local communication and participation in democratic decision-making processes (Ramasubramanian 1995; Doheny-Farina 1996)? These questions are discussed in turn.

Meaningful Information. Much evidence exists to support the notion that locality is a key variable in planning and decision making. Residents and community organizations tend to pay attention to events in their own "backyards" more closely than events occurring at a distance away (Kraft & Clary 1991; Groothuis & Miller 1994). They are more likely to preserve and restore those environmental and cultural qualities they consider important (Aberley 1993). Residents and the non-profit CBOs that serve them define problems in terms of their own territory - where they live, where they work. They seek to understand how broad environmental and social conditions affect them in their homes and neighborhoods. Communities can improve their understanding of conditions and problems through participatory processes of mapping what is important to them. Using methods and technologies which they deem appropriate, they create their own spatial representation of their locality, to understand "the complexities and important relationships within their own human and natural communities" (Fischer 1994: 34).

Technological Appropriateness. Spatial representations can be demonstrated or mapped using a variety of techniques, from children's drawings to community-sewn tapestry (King 1993) to computer-based technologies, such as Geographic Information Systems. Ideally, to map information most relevant for a neighborhood organization, information should be organized and presented to conform with the spatial boundaries of place defined by residents and their organizations. Those who seek to use maps should participate in their design, including setting the boundaries and the unit of analysis in meaningful ways (Bertrand & Mock 1995). GIS is potentially a most appropriate technology to tailor spatial representation to neighborhood perceptions because of its flexibility in manipulating diverse geographic units to analyze and present information. Also, it is potentially more useful because it is integrated with databases that can be modified as neighborhood conditions change, generating new maps with relative ease.

Modes of Use. In what ways can GIS be used by CBOs to support decisions, improve service delivery and communicate information to residents regarding environmental problems defined at the neighborhood scale? Experiences from other GIS applications offer insight; e.g., addressing environmental problems at larger scales and addressing non-environmental problems at smaller scales.

The utility of GIS as a database management, analysis and communication tool regarding environmental problems is well developed. GIS has been used to model various types of natural resource systems to support environmental management, including wetlands mitigation programs (Brown

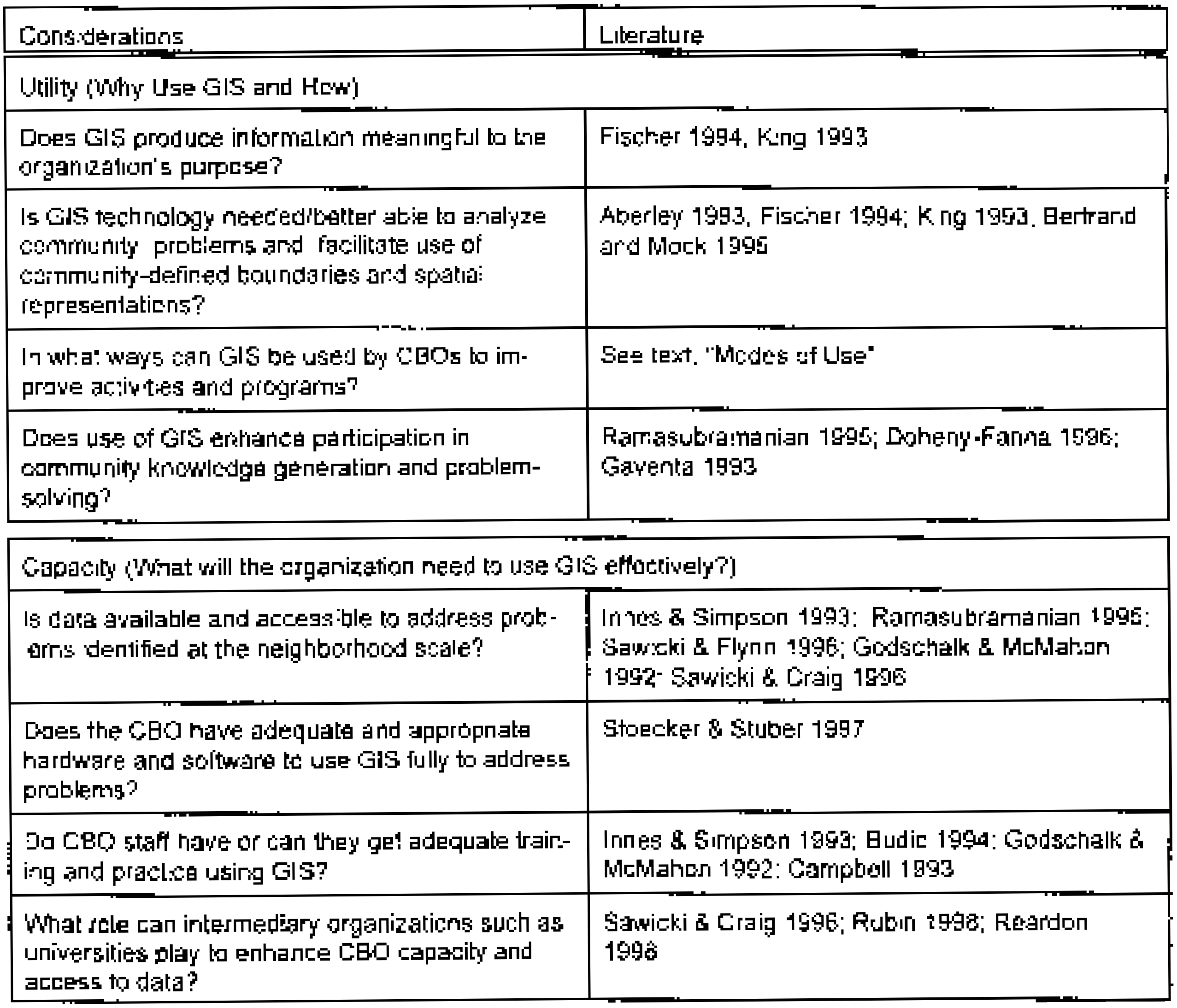
& Stayner 1995), flood plain delineation (Gallagher 1992), prediction of surface water quality (Mattikali, Devereaux & Richards 1996), and determination of bio-regional boundaries for watershed management (Aberley 1993).

GIS has been used to improve environmental aspects of land use planning (Teicholz & Berry 1983; Innes & Simpson 1993), landscape ecology (Haines-Young, Green & Cousins 1993) and land management (Gumbricht 1996; Hallett, Jones & Keay 1996). GIS has also been used to investigate environmental and public health phenomena. These investigations included monitoring air quality (Speed 1990), identifying spatial relationships between cancer risk boundaries, and air pollution (Moore 1995; Gatrell & Dunn 1995), assessing relationships between air pollution and birth and mortality rates (Lloyd 1995), and routing hazardous waste transport (Baaj, Ashur, Chaparrofarine, & Pijawka n.d.).

Overall, GIS has been shown to improve the effectiveness of government organizations at local, regional and state levels (Mills 1983; Watterson 1990; Innes & Simpson 1993; Budic 1993; Budic 1994). Use of GIS to address problems at the sub-municipal level has begun as well. GIS has proven of high utility in charting real property changes (Hintz & Onsrud 1990), in selecting vacant parcels with suitable development characteristics (Simons & Salling 1995), and predicting residential housing prices (Clark 1997). GIS has been used for health-care planning and analysis (Albert 1994) and to evaluate the efficiency of social service delivery (Wong 1993). The use of GIS to address problems experienced at the neighborhood scale is relatively less documented. Will the use of GIS for environmental problems prove as useful to CBOs as the experiences of other organizations working at other scales and for other purposes?

Enhanced Participation in Problem-Solving. Finally, will use of GIS technologies enhance participation in knowledge generation for problem solving? In what circumstances will electronic technologies, including GIS, offer new op-

***Table 1** Relevant Considerations for CBO Use of GIS*



Considerations	Literature
Utility (Why Use GIS and How)	
Does GIS produce information meaningful to the organization's purpose?	Fischer 1994, King 1993
Is GIS technology needed/better able to analyze community problems and facilitate use of community-defined boundaries and spatial representations?	Aberley 1993, Fischer 1994; King 1993, Bertrand and Mock 1995
In what ways can GIS be used by CBOs to improve activities and programs?	See text, "Modes of Use"
Does use of GIS enhance participation in community knowledge generation and problem-solving?	Ramasubramanian 1995; Doheny-Farina 1996; Gaventa 1993
Capacity (What will the organization need to use GIS effectively?)	
Is data available and accessible to address problems identified at the neighborhood scale?	Innes & Simpson 1993; Ramasubramanian 1995; Sawicki & Flynn 1996; Godschalk & McMahon 1992; Sawicki & Craig 1996
Does the CBO have adequate and appropriate hardware and software to use GIS fully to address problems?	Stoecker & Stuber 1997
Do CBO staff have or can they get adequate training and practice using GIS?	Innes & Simpson 1993; Budic 1994; Godschalk & McMahon 1992; Campbell 1993
What role can intermediary organizations such as universities play to enhance CBO capacity and access to data?	Sawicki & Craig 1996; Rubin 1998; Reardon 1998

portunities for citizen participation in science-intensive environmental decision making? (Ramasubramanian 1995; NCGIA, 1996). Such participation is a condition for neighborhood residents and their organizations to gain more influence over decision making processes that affect them. However, an equally likely scenario for the use of new information technologies is that existing inequalities in accessing information will lead to increased social polarization and segmentation (Castells 1989; Armstrong 1995). Great uncertainty exists whether new technologies can be adopted in ways that empower traditionally disenfranchised citizens as they seek to influence environmental decision making and improve conditions in their communities. [3]

Capacity

What will CBOs need to use GIS effectively? Have the necessary data been collected and made available (Sawicki & Flynn 1996; Sawicki & Craig 1996)? What means exist by which to gain access to data? Do CBOs possess technologies to connect to agency databases (Campbell 1993; Stoecker & Stuber 1997)? Does the CBO have hardware and software needed to use GIS (Stoecker & Stuber 1997)? Do CBOs have the skills needed to use GIS effectively, or can they get needed training (Innes & Simpson) and from where (Ruben 1998; Reardon 1998)? These questions are discussed in turn below.

Data Availability and Access. Participation by community-based organizations in decisions that affect their neighborhood is based in part on the availability of and access to information (Desario & Langton 1987; Ramasubramanian 1995). Availability of data relevant to a particular environmental concern defined by the neighborhood residents is key. Much of the environmental information sought by community organizations has been assembled by environmental and health agencies of federal, state and local governments. Is the agency that holds the information willing and able (both technically and legally) to transfer information readily? Given the more traditional focus of CBOs on community development and social services, do residents and CBO staff know what sources of environmental information exist and its significance one obtained? Such knowledge is key to support use of a new technology such as GIS (Godschalk & McMahon 1992; Innes & Simpson 1993).

Access to data might prove a second challenge. CBO GIS users must know how to retrieve data through a variety of media (diskette, ftp, Internet) and be capable of manipulating data into useful formats. A working knowledge of computer operations and other data base management software is required (Campbell 1993). We anticipated that the format in which data is transferred can significantly increase data management and input requirements for small community-based organizations, possibly precluding acquisition and use entirely.

The use of the Internet as a data source is of particular relevance for CBOs. Agency and non-governmental organizations are today offering more and more information via computer-based information technologies (Naisbitt 1994) such as Internet web sites and E-mail list-servers. While most data that are collected and produced by the agencies still remain available only through mail or visits to agency district or regional offices, some agencies (particularly at the federal level) are replacing more traditional access mechanisms such as brochures and telephone information personnel with on-line mechanisms (Coder 1997).[4] . Geographically based information is available by state, by county, and by zip code. CBOs with GIS capabilities could manipulate such data to address problems affecting the neighborhood as they define it. When Internet connections are efficient and the desired information is available, downloading data from the Internet can save time-pressed CBO staff hours of effort, but only with modems with adequate speed to load graphically intensive sites and large databases.

Adequate Hardware & Software Technology. Transfer and manipulation of data depends on adequate technology (hardware and software). How likely are CBOs to have these technologies? A 1996 survey of CBOs in seven Ohio metropolitan areas demonstrates the issues related to hardware capacity. Of 189 organizations responding, only 38 had hardware capacity the researchers considered needed to support Internet access minimally [5], which would indicate even fewer would have hardware adequate for GIS software use. Only three organizations indicated access to and use of the Internet and only five indicated they currently used GIS. While significant obstacles to GIS use exist, the desire for use of GIS was strong: of the 189 organizations, approximately 60 indicated they wanted to obtain GIS (Stoecker & Stuber 1997).[6] The survey also indicated that many CBOs planned to incorporate better computer equipment through their budgeting processes. Such actions should increase their access to and capability to manipulate information, whether available through traditional means or over the Internet, to use GIS to bolster their planning and participation activities.

User skills. Experience from GIS use in local and state level planning agencies indicates that effective use of GIS requires significant training and on-going opportunities to practice and improve familiarity with GIS and data support software (Innes & Simpson 1993; Budic 1994). While GIS as a technology has great power when used by the highly trained and practiced user, users in organizations such as CBOs may not have the advanced skills or time to use GIS to the same potential. The advent of more user-friendly “desk-top” GIS software was predicted to enable more organizations to begin using the technology (Van Demark 1992). Recent work by the National Center for Geographic Information and Analysis (NCGIA) questions whether CBOs will possess skills and access to data needed to make GIS most useful, however (NCGIA 1996).

Role of Intermediary Organizations. From where do CBOs get technical assistance for using GIS? What kinds of technical assistance will be needed? In many communities, intermediary organizations assist CBOs through a variety of programs and financial support. What role can these intermediaries play regarding use of GIS? We were particularly interested in exploring the role that universities (as institutions) and students (engaged in experiential learning classes) might have to support more effective use of GIS by CBOs. The benefits of university/community partnerships to community improvement are well documented. Universities assist CBOs in many aspects of planning and problem-solving, including problem definition and program development, asset mapping, training and technical assistance, program evaluation and organization and leadership training (Rubin 1998). These efforts can lead to more effective planning and problem solving. Common to analyses of effective university-community partnerships are community capacity-building efforts (Rubin 1998; Reardon 1998).

The Client and Study Area

The St. Clair-Superior Coalition, the project client, is a community development organization recognized and partially funded by the City of Cleveland. The organization has five full time staff members who organize neighborhood block clubs, coordinate rehabilitation of multi-family and single family housing, provide marketing assistance to merchants, administer a job search assistance program, and administer a city-sponsored pediatric lead education program. The Coalition works in the St. Clair-Superior neighborhood, located in the north east section of the City of Cleveland near the downtown area (Figure 1). [8]

Land use in the neighborhood is a mix of residential, industrial and retail. The Lake Erie shore area consists of industrial facilities, an electricity-generation plant, several marinas and a city park. An interstate highway separates the residential areas from the lake. The neighborhood's eastern boundary is comprised of Rockefeller Park, which joins at the lake with Gordon Park, the primary access point to the lake. In the western end of the neighborhood, industrial facilities and small residential streets are contiguous, exemplifying many urban neighborhoods settled in the late nineteenth and early twentieth centuries [9]. Discharges of toxic and other smoke and vapors from several dozen industrial facilities are a significant challenge to a healthy resident life in this part of the neighborhood.

St. Clair-Superior is a low-income neighborhood, with 1989 median household income at $15,000. Forty two percent of the residents live at or below the federal poverty level. The neighborhood's approximately 12,000 residents are culturally and ethnically diverse: 56% are African American, 36% are white and 7% are Hispanic.[10] The neighborhood is typical of many older urban neighborhoods, with problems of abandoned housing, vacant parcels, high unemployment and environmental degradation. The neighborhood also, however, has a rich ethnic mix of older Slavic residents and younger African American and Hispanic residents who have begun to work together to restore their living environment.

During 1994, the Coalition hired Northern Ohio Data Information Service (NODIS) at the Levin College of Urban Affairs, Cleveland State University, through a Community Development Block Grant from the Department of Housing and Urban Development. A base map, which was created by digitizing the assessor's parcel map for the neighborhood, was completed for the service area of the organization (Figure 2). The Coalition acquired GIS software and a staff member was trained by NODIS in the use of MAPINFOTM. At the time of our project (1996-1997), the organization used GIS to track crime watch activities and participation in storefront renovation programs in the neighborhood. The organization also wanted to expand use of GIS to address the environmental concerns of several street clubs, which included air pollution, vacant land, storage of hazardous materials and access to the lakefront.

Project Design

The Coalition's immediate need was to acquire data to address environmental problems, an activity for which they had little time for a comprehensive approach. Our objectives to meet the client's needs were three: 1) to assemble environmental data to address the Coalition's environmental concerns (described below); 2) to transfer the data and any maps to the client for their continued use; 3) to identify and document data sources, means of retrieval and contact persons at relevant data provider organizations to ensure that information could be updated by the Coalition after the project ended. Our broader objectives were to test the relevance of our research questions and gain insight through a practical and reflective GIS application.

The environmental conditions that shape the quality of life and health status of neighborhood residents today arise from a combination of the environmental legacy of late-nineteenth century development of the neighborhood and present-day environmental policies and practices. The client was most concerned with land contamination on vacant lots and the poor air quality in the neighborhood caused by the presence of several facilities that discharge fumes and particulates on parcels contiguous to residences. We suggested that a broader inventory to develop a profile of the neighborhood's environmental hazards and assets would help set planning priorities. We also suggested that historic data on the development of the neighborhood would serve to address land use change and its legacy relevant to present-day land conditions. Working with the client, we

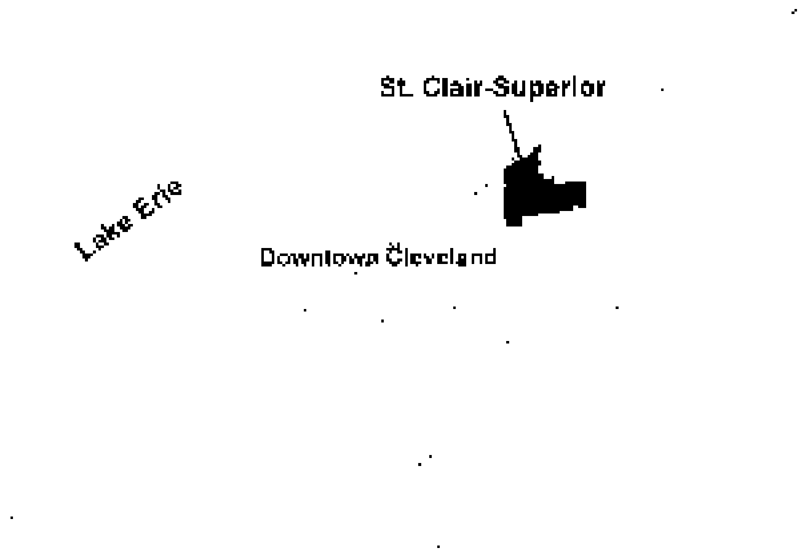


Figure 1 *St. Clair-Superior Neighborhood, Cleveland, Ohio*

identified the constituent parts of the inventory for the neighborhood: land use by focusing on vacant parcels and those with potential contamination from underground storage tanks (USTs) or past uses, and waterfront change, as well as facilities with Clean Air Act Title V permits to discharge into the air; facilities reporting to the Toxic Release Inventory (TRI); and facilities in the neighborhood storing or using hazardous materials. [11]

The inventory was completed by ten students in an environmental studies class, assisted by the CBO staff. Data was retrieved for the inventory from a variety of local, regional, state and federal agencies using a wide range of techniques, including telephone calls, diskette copies retrieved at agency offices, and the Internet (Table 2). The data was loaded into MAPINFOTM browser tables and mapped. The project inventory was completed over a ten week academic quarter, with six weeks for data needs identification and collection, and three weeks for production of maps and other materials for the client. Each student was required to devote four to eight hours per week to the project. The environmental history, completed by the author and a graduate student, took approximately 50 hours of research time.

For several components of the inventory we describe below the issues relevant to data collection and mapping processes and the effect of using GIS on the CBOs activities. These results are then summarized with their general implications for other CBOs contemplating GIS applications. Table 2 also presents the limiting factor for our particular application and summarizes the likelihood that data is available and accessible more generally for the elements considered in the study.

Gis Application and Results

Historic Land Use and Development

We began searching for historic information to create a general picture of how environmental conditions in the neighborhood changed as the neighborhood developed. This environmental history documented the environmental conditions of the neighborhood through time as these were changed by infrastructure development, industrial production, commercial and residential expansion, and development of public parks.

The flat lake front plain of the St. Clair-Superior neighborhood proved an ideal location for intercity railways carrying iron and coal to fuel Cleveland's industrial expansion of the late nineteenth century. Many large companies, including various iron, steel, brass and other metal companies, several chemical plants, construction and bridge-building companies, soda works, a coke company, a motor production company, and later, two electric generating plants, located or expanded operations in the neighborhood. These facilities were located east and west of present-day E. 55th Street , predominantly along the lake shore, but were also intermingled with the residential and commercial areas developing along St. Clair and Superior Avenues (Figure 2). [12]

The history of mixed land uses makes the presence of land or building contamination in the neighborhood likely. When a parcel is slated for redevelopment by the Coalition, the Coalition completes a careful study of past land uses. The Coalition sought a method to identify areas of the neighborhood with a higher probability of historic contamination, a method that could serve as an early warning system. We focused on one commercial corridor in the neighborhood that has many older buildings and parcels in need of redevelopment. Information about historic location of businesses that might have deposited materials on the lot was taken from a set of business indexes published from 1880 through the 1930s, when the spatial development of the neighborhood was virtually complete. We discovered that few of the historic addresses matched present-day addresses used by the county assessor. Parcel addresses and parcels had changed substantially in the 12 decades we sought to document. Our geocoding of many of the parcels required comparison of several decades of Sanborn maps with the business indexes in order to assign the correct address to the parcel. Using this process, we identified the parcels with historic uses likely to predict contamination of the parcel by metals, chemicals or other hazardous materials. While Sanborn maps are readily available in most communities, the business directories might be less typical. We conclude, however, that the use of GIS to comprehensively map historic parcel land use information proved very time consuming and would not likely be done by a CBO without additional assistance.

A second land use activity focused on vacant parcels now in the City's land-bank program. These parcels are available from the City for purchase for $1 by neighborhood residents, developers and community development organizations. Students designed and carried out a site reconnaissance for several of the commercially and residentially zoned lots. An 8.5" x 11" lot map for each site was generated directly from the GIS parcel map. Each site reconnaissance team used the lot map to record site characteristics taken from the standard elements in a Phase I investigation on a walk-through of the site.[13] A legend of graphic symbols to indicate the presence of a site feature was generated using characters from MAPINFO ™.[14] These symbols were hand drawn by student and resident site reconnaissance teams onto the lot maps and then transferred to the GIS parcel map. The technology facilitated use of the spatial boundaries of a particular environmental problem as defined by the CBO. GIS provided a tool for developing a replicable site reconnaissance process that the Coalition can use in the future on other lots and other CBOs could use as well to encourage participation by neighborhood residents.

Significant shoreline changes accompanied the economic and physical growth of the neighborhood. The early railroad lines required in-fill of the lakeshore; between 1894 and 1895, piers and docks were built all along the neighborhood shoreline to service the many industrial facilities developing along the lake. Between 1898 and 1910 breakwaters were completed to protect the lakefront for warehouses, factories and docks. Refuse piles of industrial and municipal waste grew on the lakeshore during the 1920s and 1930s. In the 1930s a new lake shore boulevard was built upon land "occupied by the city dump..." (Cleveland Press 1933). Over the next 25 years, a series of successively wider and more modern roads was built along the lake, eventually bisecting the pride of the neighborhood, a park donated in 1892 to the City by prominent citizen William Gordon (Kennedy 1896; Orth 1910; Avery 1918). Today, Interstate 90 is the latest iteration of the lake shore road.

As a result of the long history of intensive land use and infrastructure development, Lake Erie is virtually cut off from the St. Clair/Superior neighborhood (and the rest of Cleveland) by the freeway, railroads, industries, and power plants. The only significantly accessible lakefront use is for fishing off the remaining piers and boating from one of the private or public marinas that now line the shore. Figure 3 summarizes the changes to the Lake Erie shoreline.[15] A colorful map delivered to the client shows very clearly how the lakefront had changed. From the environmental history, the residents have achieved a better understanding of the environmental legacy of these changes. A Coalition board member and neighborhood resident acknowledged the power of the map for demonstrating that, despite its apparent permanency, the lakefront has indeed changed, and can indeed be changed again. The Coalition is using the lake front history and the map as a baseline for a neighborhood waterfront planning process to link the neighborhood with the lake once more.

Pollution Hazards

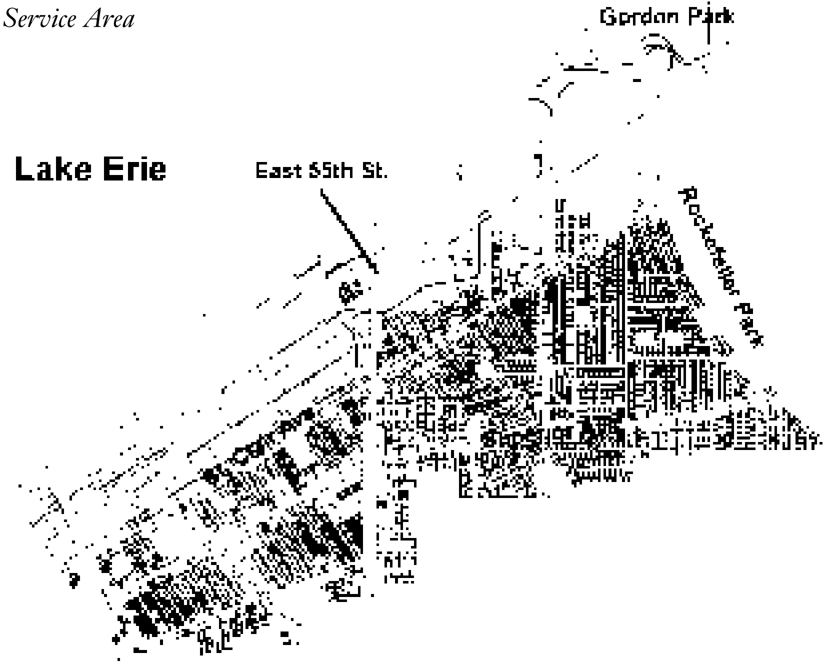
Pollution is a significant problem for the neighborhood because of the close proximity of industrial facilities to residences. The Coalition had on occasion helped residents investigate emissions from factories in the neighborhood; however, it was now interested in a more comprehensive accounting of the location of four pollution hazards; underground storage tanks (USTs), permitted discharges into the air, discharges reported to the Toxic Release Inventory (TRI), and on-site storage or use of hazardous materials. One or more of these problems often characterize older urban neighborhoods. Students identified and worked with a contact person at each administratively responsible agency to identify at what scale or unit of geography their data was available. This process allowed us to identify the level of compatibility of the agency data with our client's service area and how that data might be accessed and reformatted to suit the client's needs.

Underground Storage Tanks. The Coalition sought the location of underground storage tanks in the neighborhood to anticipate presence of contamination when considering parcel redevelopment. Information on the presence of underground storage tanks has been compiled by Ohio's Bureau of Underground Storage Tank Register. We retrieved our data from the State of Ohio and mapped

***Table 2** Summary of Data Issues for GIS Applications by CBOs*

Feature Mapped	Data Source(s)	Data Transfer Mode	Transformation Required	Limiting Factor(s) in Case	Likely Data Availability
Historic land use changes	Sanborn maps; newspaper articles; historic maps at local library; several histories of Cleveland	hand digitizing of maps	assemble maps; reconcile different scales; infer spatial location based on written accounts and historic photographs	time resources; access to digitizer	Sanborn maps widely available, local archives in hard copy likely available
Vacant lots	county assessor tax records	diskette copy retrieved by student	ASCII delimited table to MAPINFO™	hard copy more likely, time for data entry	assessor information widely available in hard copy
	City of Cleveland Land Bank Program	hard copy	data entry	time resources, manipulation of format	highly variable
Underground storage tanks	Ohio State Bureau of Underground Storage Tank Register	data diskette copy through mail	Excel spreadsheet to MAPINFO™	state readiness to provide	state data availability variable
Title V air permits	Ohio Environmental Protection Agency	diskette copy through mail	State manipulation of software- specific tables to ASCII: change to Excel to sort to MAPINFO™	state readiness to provide; data is for location of emission point, not chemical emitted	permit review available through special request , subject to legal review
Toxic Release Inventory	USEPA Envirofacts Warehouse website	Internet	download table to Excel; upload to MAPINFO™	Internet access	federal website and many other providers
Storage of hazardous materials	Cuyahoga County Emergency Management Division	diskette copy	county manipulation of data to ASCII file; upload to MAPINFO	$ charge for data (staff time to prepare)	federal law requires program; data available upon request in most communities

Figure 2 *Parcel Base Map for St. Clair-Superior Coalition Planning and Service Area*



it onto the parcel base map. The Coalition determined that this data, when combined with the visual site reconnaissance, will indicate good locations for future development and an early warning for the need for a formal Phase I investigation. [16]

Permitted Air Discharges. Discharge of pollutants into the air is the most long-standing concern of neighborhood residents. Residents have frequently reported emissions of particulates and the presence of objectionable odors from many industrial facilities. Data on air discharge permits required by Title V of the Clean Air Act were obtained from Ohio EPA's Air Permit Section in Columbus, Ohio. The database consists of each discharge point for which a permit is required (that is, each boiler, mixer, blower, evaporator, stack, etc.). The highly industrialized neighborhood contains 800 of these discharge points. [17] To map the information, we sorted by address, geocoded these to the parcel map, and produced a map of facilities in the neighborhood with Title V air discharge permits. We mapped the facilities onto both the parcel map and the TIGER/Line file base maps. Use of the parcel map seemed more appropriate for understanding the geospatial relationship of the residential lots to the air discharge points, for the problem defined was the fall-out from specific emission points into these lots. This approach also reflects the client's need to address problems within its own service area.

The Coalition is using the air emissions data for additional projects. The emission points will be cross-matched with typical emissions from these types of discharge points (using Standard Industrial Codes) to help prioritize which air discharge permits to request for review at the appropriate agency office to determine which pollutant is emitted and in what amount. As yet that information is not available by other means. The location of the emission points will then be compared to a wind rose to assess the potential affect of the emissions on the neighborhood.

Toxic Release Inventory. Title III, Section 313 of the 1986 Emergency Planning and Right to Know Act (EPCRA) requires certain industrial facilities emitting certain toxic chemicals exceeding a certain amount report any off-site and on-site release or disposal from their facilities to the United States Environmental Protection Agency (USEPA) on an annual basis. USEPA compiles these reports into the Toxic Release Inventory (TRI). TRI data are available through several Internet sites which vary in the level of detail presented. We assessed these and found the USEPA web site Envirofacts to be most useful. [18] Nineteen facilities in the neighborhood report to the TRI. Again, we produced maps using both the parcel and TIGER/Line base maps. The parcel map was more relevant for TRI data concerning location of shipments and on-site discharges, as neighborhood residents would seek to know what was happening on the parcel next door. The TIGER/Line map was used to map the TRI air emissions and included several of the facilities that lie west and southwest of the neighborhood. These facilities can directly affect air quality in the neighborhood because of the predominant west-southwest to east-northeast direction of the wind. A plume analysis would have been most useful here, but was beyond the skills of the CBO staff person and the students involved in the project.

Storage of Hazardous Materials. Many industrial and commercial facilities in the neighborhood store large amounts of hazardous materials used in production processes or maintenance on-site. Each community is required by EPCRA to compile a database of these facilities and make plans for evacuation of nearby population in an emergency (any large release of materials). Information on storage of hazardous materials was assembled from data provided by Cuyahoga County Local Emergency Planning Committee (LEPC).[19] These data were mapped onto the parcel base map. The Coalition will compare these locations with schools, churches, playgrounds and other locations in the neighborhood to assess their proximity.

Case Study Results and Generalized Observations

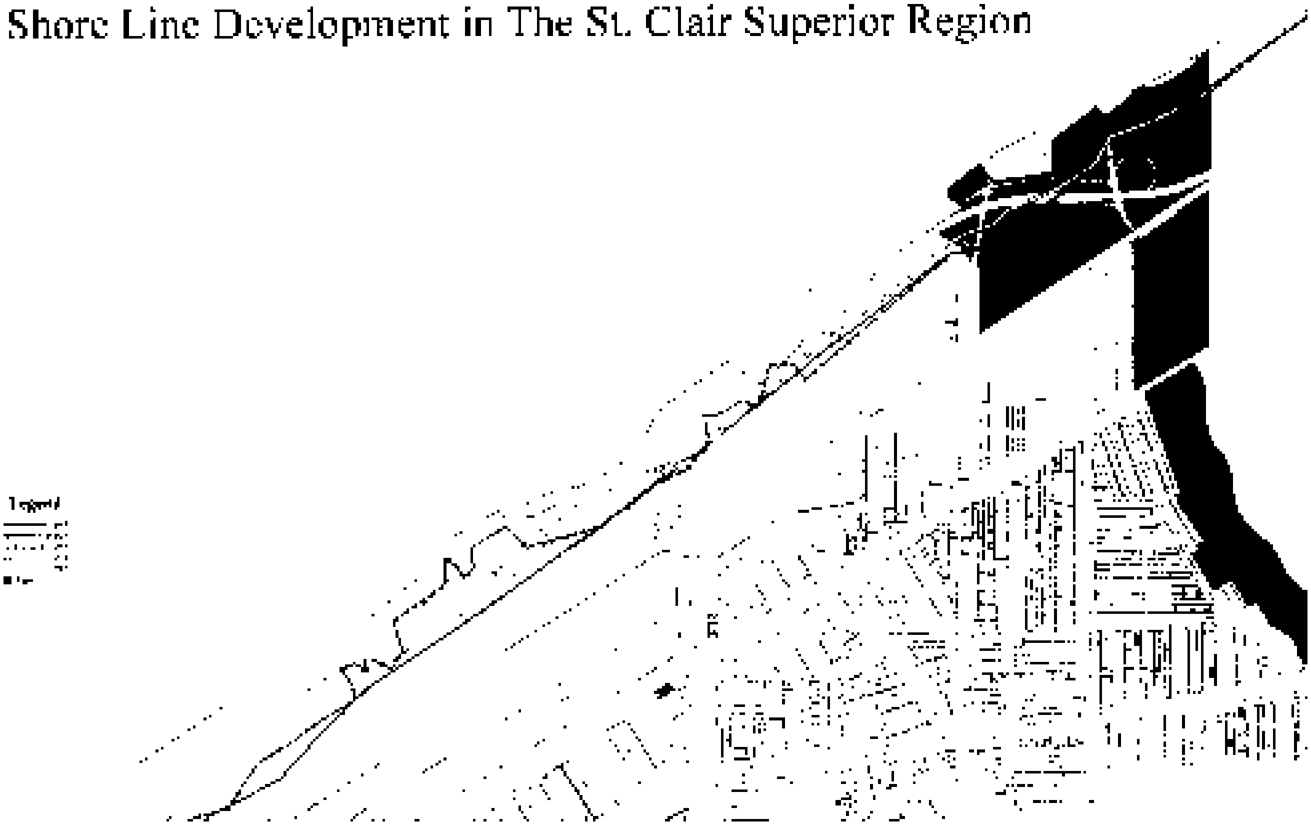
The results form our case study, we believe, hold import for other community-based organizations considering using GIS tools to address environmental concerns in their neighborhoods, for intermediary organizations, and for data providers. In this concluding section we review the eight research question areas summarize in Table 1.

Utility

Meaningful Results. For most of our objectives for the client, GIS proved useful. GIS helped the CBO to analyze the community's environmental problems by improving their knowledge of the spatial distribution of a set of environmental hazards. Prior to our efforts, the CBO did not have a comprehensive and clear picture of the number and location of these hazards. GIS produced information meaningful to the CBO's efforts, particularly in creating and communicating the baseline inventory of conditions. It has improved communication by the Coalition to its board members and residents. Copies of the GIS map are used in environmental outreach by the CBO staff. The Coalition is also now using the maps for continued analysis of air discharges and health concerns of the residents, thereby supporting better decision making.

For urban CBOs more generally, GIS can be used to generate information about a variety of social, economic and environmental concerns. GIS can be a powerful tool to help CBOs understand conditions in the neighborhood to the extent that data about the neighborhood can be collected and mapped by the CBO or obtained from government or non-governmental data providers. Perhaps the most meaningful information generated through use of GIS is that which places the neighborhood as a small area of territory in its city-wide or regional context, allowing neighborhoods to understand how broader environmental conditions contribute to conditions in their neighborhood. On the other hand, for some information, such as values and perceptions residents hold about the neighborhood, other means for communicating information, such as mod-

Figure 3 *Historic Changes to Lake Erie Shoreline in the St. Clair-Superior Neighborhood.*



els, posters, photo essays, or hand-drawn maps might be more appropriate and needed.

Technological Appropriateness. With the Coalition we were able to define spatial boundaries and select the spatial representation of the neighborhood that fit the problem addressed and the information desired. The client asked that the data be assembled for their service area, which encompassed approximately 1.5 square miles of urban territory. That geographic unit did not correspond to others typically used by the City of Cleveland (Statistical Planning Areas), the State of Ohio (zip code) or the U.S. government (counties, zip code and census tracts) to organize data. We anticipated some difficulties with the match between the structure of environmental data available from various agencies and the client's need given the unusual boundaries. GIS proved useful in resolving these issues of diverse units of geographic analysis.

Because GIS places high resource costs on an organization, CBOs should approach GIS cautiously. GIS will be most useful for two aspects of CBO environmental problem-solving activities: tracking changes in neighborhood conditions over time; and analyzing spatial relationships among socio-economic and environmental concerns on a parcel-by-parcel, block-by-block, or census tract-by-census track basis. These uses depend on the availability of relatively well-developed data. (described below).

Our mapping activities depended on existence of a parcel map for the service area of the Coalition. Planning and management territories are defined according to their particular purpose (Guttenberg 1993). In urban neighborhoods, territory tends to be socially-defined (rather than biophysically-defined) and created to reflect more traditional social planning and service provision needs. GIS was useful because it allowed us to determine larger and smaller scale views of the neighborhood as dictated by each environmentally-defined region. In our project, use of the two base maps (TIGER and parcel) was appropriate, depending on the information we wished to analyze and communicate. For other CBOs, the feasibility of using GIS as we did depends on existence or development of the appropriate base maps.

Existence of a GIS parcel map for a given neighborhood depends either on efforts by county and local governments to create parcel maps for their entire jurisdictions or on the financial resources of CBOs. As more planning and engineering agencies adopt GIS, which appears to be the case (Gallagher 1992; Budic 1993), the likelihood that city- or countywide parcel base maps will be available to CBOs increases. Alternatively, access to a parcel base map might depend on creation of the map by the CBOs themselves, which is a labor-intensive exercise, often requiring that a county assessor's map be digitized by hand (Simons & Salling 1995). This can be cost-prohibitive for many CBOs, which are not likely to have the resources to purchase a digitizer. The federal grant initiatives targeting computer hardware should increase the resources available to CBO, but these funding sources will likely remain highly competitive.

We recommend an alternative strategy. In many communities, intermediary organizations, local governments or universities provide technical assistance and training to CBOs. These organizations could coordinate and house a program that would purchase and maintain a digitizer and plotter and allow CBO staff trained in GIS to use them to create and print parcel-based maps. Such an opportunity would make CBO less dependent on finding consultants to create maps and would provide greater access to technology. This kind of sharing has been pursued in several localities to serve the needs of local governments (Mitschele 1996; American City & County 1997) and could be developed to include CBOs.

Problem-solving Participation. The information we provided using GIS has served to enhance and stimulate participation in environmental problem-solving in the neighborhood. The GIS maps and the inventory document the current status of problems and have helped the Coalition identify priorities. The site reconnaissance exercise was more consistently documented using output from the GIS maps. The maps produced have spurred additional interest in leaking underground storage tanks and air discharges in the neighborhood. We are now working with the Coalition to address information needs for these issues.

The GIS project stimulated a broader effort to build capacity in the neighborhood. In the course of their research on current environmental conditions the students compiled background information on the regulations and laws governing environmental quality conditions, the agencies that are responsible for regulation, and potential financial sources to fund neighborhood environmental improvement projects. Students assembled an environmental resource guide that accompanies the data sets and maps. The resource guide has allowed the Coalition to increase its outreach concerning environmental issues in the community. [20] The resource guide and mapped information also smoothed the transition among Coalition staff members, as a different staff person assumed responsibility for the lead and environmental programs the year following our work.

A standing Environmental Committee of 6 residents was recently added to the Coalition's neighborhood watch and housing committees. This committee is now developing strategies to address USTs, storage of hazardous materials in the neighborhood and air emission complaints. At one meeting, a new committee member held up our initial map of USTs and asked if we knew where to get additional data on which tanks were leaking, a direct link between information generated using GIS and enhanced resident participation.

Based on our experience, the use of GIS can enhance community knowledge generation and problem solving, but only to the degree that GIS is seen as a tool useful to problem-solvers, not as a problem-solving mechanism itself. CBOs that have a well-developed organizational capacity for problem solving and include neighborhood residents in their activities will find the greatest benefit from GIS to improve their analytical capabilities and resident participation. However, we also expect that if GIS is purchased by a CBO that does not have strong problem solving skills it will likely be underutilized.

Capacity

Data Availability and Accessibility. Availability of data to address problems identified in our neighborhood application was mixed (See Table 2). For example, while we found some pollution emission data available on-line, the Title V data, though collected, was not readily available in a useful format. We acquired data on the emission points in the neighborhood, but data on the specific emissions (kind and amount) from each of these points is available only through a request to review the facility discharge permit at the City of Cleveland's Air Division office. Each request must be reviewed by the city's legal department to assure the facility's owner is not involved in a legal proceeding, therefore, access to the permits can take several weeks or months and during a one-quarter class this was not feasible. It is likely that a similar situation exists in other communities, whether the air emission program is administered at the city level, as it is in Cleveland, or at the state level.

Still other data of interest to the Coalition and residents has not been collected and assembled. For example, many residents have concerns about the health effects of emissions from industrial facilities. They reported to us that their neighbors suffer a variety of health problems, including several cancer victims in a family and frequent respiratory problems, including asthma in adults and children. In the case of asthma, data that could be spatially analyzed is not available because asthma, unlike elevated pediatric blood lead levels, is not a "reported" disease. [21] We suspect that this particular gap in data availability is relevant to urban neighborhoods in general, where it is believed that pediatric asthma is more prevalent. A change in federal or state policy designating asthma as a "reported" disease -- would allow CBOs using GIS greater capacity to assess the spatial distribution of asthma in their neighborhoods. More generally, we recommend that USEPA and state and federal public health departments develop mechanisms to collect spatial data on other diseases that can be caused or aggravated by environmental pollutants and make it available for public use as well. Environmental health data, when not collected, stored and accessible, thwarts community-based efforts to improve conditions that support a healthy life for residents.

While waiting for any state or federal policy changes, CBOs and their community partners can devise alternative methods for creating information from data that is available. One Cleveland project, for example, is now investigating the use of known incidences of elevated pediatric blood lead levels as a marker for incidences of pediatric asthma.[22] Limited resources require such creative strategies to utilize available spatially-referenced neighborhood-level data to the greatest degree possible. CBOs can also generate data about the neighborhood by house-to-house surveys of resident's perceptions of the environmental quality in the neighborhood, health problems they experience, etc.

It is likely that many CBOs will find it difficult to mobilize the resources needed for a more comprehensive data assembly and mapping alone, as was documented by Barndt & Craig (1994) and Sawicki and Craig (1996). Here the role of a local university or local government can prove key in assisting an organization. [23]

A wide range of agencies at federal, state and local levels store environmental data. The high data input demands to use GIS to its full potential require knowledge of the various sources of data, which is based on a good knowledge of which agencies are responsible for what information through their regulatory function. These are of particular concern for use of GIS by CBO to address environmental problems or create a comprehensive picture of environmental conditions in their neighborhoods given their more traditional focus on housing and economic development projects and programs. Community-based organizations can learn over time where and how environmental information is available, [24] however, their ability to acquire it would be improved to the extent that data providers can decrease the "transaction" costs for CBOs. Our study well-illustrates the need for "user-oriented" design of data accessibility, including data that will form the basis of GIS as described by Bertrand and Mock (1995). As regulatory agencies at the federal and state level strive to provide more data, greater consideration should be given to whom the end-user of that data may be. The way data are organized and retrieved should be modified to accommodate citizen and community-based organization staff end-users. [25]

We urge environmental agencies that are required to provide data to the public conduct outreach to CBOs regarding the availability and access methods for data that they hold. CBOs have far greater contact with urban residents than most environmental agency staff and we believe that the regulatory agencies could better fulfill their efforts toward community-based environmental protection by such outreach. Universities and local environmental organizations could prove useful partners in this endeavor as well and provide on-line metadata documentation of GIS data in a locality. For example, the NEOEDEN Project, [26] which provides metadata on environmental spatial data on-line, is sponsored by four universities in northeast Ohio.

Hardware/Software. These proved a significant issue for the CBO in our project. The CBO has three computers; only one has a 486 processor. GIS and the Internet require fairly advanced computer speed and capacity, which, according to Stoecker and Stuber's (1997) study in Ohio, are likely to exceed that typically found in CBO offices. Features and capabilities of GIS software vary by manufacturer and version. The CBO we worked with had MAPINFOTM Version 3, but did not have a good spread sheet program, which we found very useful in readying data for MAPINFOTM . The organization did not, and does not at this writing, have Internet access. This set of characteristics is not the best situation in which to develop GIS as a decision-support tool. Internet conditions appear to be similar to those faced by many CBOs, and the presence of GIS is rare. However, in the Ohio study, 65 of 189 CBOs used database and spreadsheet software. These are often critical for preparing data to use in a GIS program.

Finding funds for hardware and software maintenance and upgrades is a key prerequisite for sustained use of GIS for CBOs. Unfortunately at this time, US federal funding is highly competitive. Intermediary organizations seeking to support CBOs could create a hardware exchange program or facilitate donations of less-than-leading edge hardware from corporations and government agencies as they upgrade their hardware and software.

GIS Training and Practice. CBO staff capacity and skills was a key variable in our project, as it was in studies done by Innes & Simpson (1993) and Budic (1994). A staff person in the CBO had been trained in MAPINFOTM by the university prior to our project. The staff person was a community project manager whose activities were split among GIS and other responsibilities. We know that the presence of a GIS-specialized staff person who has the time for improving skills and developing data bases has been a key feature of successful use of GIS in municipal and county planning agencies (Budic 1994); however, it is unlikely that even when a CBO staff person is trained his or her time will be devoted exclusively to GIS. Shortly after our project began, the GIS-trained person assumed the position of Director of the organization. We doubt that the staff person will be able to maintain working GIS skills given the shift in duties. Personnel changes in non-profit CBOs are frequent, raising the possibility that the GIS-trained person may assume other responsibilities or leave. This is a serious detriment to sustained use and improvement of GIS capacity in any CBO.

Mitigation of these problems will be difficult, requiring a comprehensive approach. The resolution of both data management problems and user capacity to make GIS a useful and effective tool for CBOs to address environmental problems depends on creation of an effective information management system in the organization. Information management includes setting priorities, identifying information needs to address these priorities, building capacity to understand and use sometimes highly scientific and technical data, processing that data into information that is meaningful, and communicating that information effectively to improve participation and decision making (Kweit & Kweit 1987; Kellogg 1998). Our project confirms the need for such a system described in the literature. Only when community-based organizations become good environmental information managers will they be able to access, understand and use information as part of their ongoing community development and environmental protection efforts.

Identifying the conditions needed to create this system for community-based organizations is an area in need of further development. From our experience, such a system centers upon adequate and sustained training and technical support for CBOs in a wide variety, including knowledge of basic scientific concepts, including risk and the use of statistics for data analysis, as well as computer skills.

Based on our community-based experience, we suspect that understanding scientific data would be most challenging among CBOs because of their relative shorter experience regarding environmental issues. Understanding the relationship between environmental conditions and human health is particularly challenging, and requires significant familiarity with scientific evidence. CBO staff must also be able to recognize the significance or meaning of data once obtained. In a recent study, Sawicki and Craig (1996) found that CBO staff seeking assistance in obtaining data from a set of information providers across the US often did not know how to read the data. They could not identify its meaning once analyzed, needed help putting data into its broader context, and needed to learn how to use information and analysis to affect policy or its administration.

We suggest here again that universities can have an important role in working with CBOs. Technical assistance concerning environmental problems in urban neighborhoods must include training in basic concepts such as risk and risk assessment, particularly as these structure agency regulatory emphases and data collection efforts.

To effectively use GIS, organization must be able to manage and create databases, which will likely be met with difficulty by smaller CBOs. Regarding existing use of computers for databases, the evidence we have is somewhat encouraging. In Stoecker and Stuber's study (1997), 65 of 189 CBOs indicated they currently use database and spreadsheet software. If the CBO wishes to adopt GIS effectively, the entire staff of the organization should be trained in ways to support GIS. Ideally, more than one staff person would be trained in GIS software use and those trained in GIS would include additional staff members in developing their GIS skills as well. The organization and other staff members can support use of GIS through other data management skills such as Internet or ftp transfer, use of spreadsheets and statistical analysis.

Novice GIS users require frequent technical support. From where can they receive help to answer questions concerning data, data analysis, map creation, and presentation? Universities and other intermediary organizations that traditionally offer technical assistance to CBOs on other matters can be a key locus of assistance. A carefully trained, proficient GIS user, skilled in statistical analysis, in an intermediary organization could provide technical assistance to many CBOs. This kind of program would be modeled on existing efforts to assist CBOs in data acquisition and use. [27] The likelihood and willingness of non-profit, non-university intermediaries in Ohio to perform this role is being assessed through a research project now in progress. Based on our on-going experience in one Cleveland neighborhood, all efforts must build capacity among CBO users in these programs.

Overall, our review of this GIS application found that GIS can be a useful tool for community-based organizations. Its most profound utility lies not in a particular map created, but in its effect on the CBO and the neighborhood. Neighborhood change results from what happens to the residents and staff members as they use GIS. Using GIS can provide a mechanism to stimulate the search for environmental information and for a deeper understanding of its significance. As in the use of any tool, the social change encouraged by its use is the ultimate test of its worth.

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End Notes

1. The project was an outgrowth of faculty service to the organization. The paper describes work down by an undergraduate environmental studies class and two Americorps students working with faculty and neighborhood organization staff.

2. For example, the mean size of Cleveland CBOs is 4.4 full time staff (center for Neighborhood Development 1007); in Ohio, only half the CBOs had more than 2 full time staff members in 1996 (Stoecker & Stuber).

3. Much of this debate concerning issues of GIS use and social power is occurring via the Internet, particularly in a Webster of the National Centers for Geographic Information Analysis (NCGIA), a consortium of several universities and GIS centers. URL: http://www.ncgia.ucsb.edu.

4. For example, the United States Environmental protection Agency (USEPA) is rapidly expanding Internet availability of information on its Envirofacts Warehouse Web site (USEPA 1997). Some EPA division or program sites provide a relatively user-friendly mapping function that allows the web-user to designate an areas on a map and obtain information about that area from the data base.

5. Minimally, adequate was defined as the following: a 3.1 Windows operating system, 386 processor, 8 MB RAM, a 400 MB hard drive and a 14.4 modem (Stoecker & Stuber 1997).

6. Organizations participating in the study included social service providers, settlement houses,. And community development organizations, as well as many other community-based organizations.

7. The organization's remaining funds are assembled from private foundations, federal state grants, and corporate donations.

8. All maps presented in this article were produced by undergraduate or graduate students working on the project.

9. Present-day industrial facilities include paint manufacturing, electroplating, tool and dye manufacturing, motor refurbishing, metal forging, plastic production, and printing.

10. This neighborhood profile is based on the 1990 Census.

11. The author had determined that no facilities in the neighborhood held permits to discharge to surface water.

12. Sources for neighborhood development history included Sanborn Fire Insurance maps, three excellent histories of Cleveland (Kennedy 1896; Orth 1910; Avery 1918), and a historic collection of the Cleveland Press.

13. A Phase I investigation consists of a complete history of property use and visual identification of areas that may be environmental damaged or unsafe, such as soil stains, drains, evidence of USTs, trash piles, wells, foundation remnants, etc.

14. The site features mapped included soil mounds and depressions, soil stains, types of vegetation, gravel and sand, standing water, building foundations, utility lines (gas, electric, etc.), curb cuts, rubbish and storage drums or other containers.

15. The map was created by inserting linear fragments on the basemap using topographic contours, known latitude-longitude points and details from historic narratives for guidance.

16. A formal and legally binding Phase I investigation must be conducted by a person or firm registered with the State of Ohio.

17. We received the large database on diskette from the Ohio EPA headquarters in Columbus. The database was read using spreadsheet software and then loaded into MAPINFO. The browser tables delivered to the Coalition display the types of discharge points.

18. The TRI is organized by zip code, county and latitude/longitude. Reporting data for the zip codes that contain the neighborhood area were downloaded off the USEPA Webster into a spreadsheet program and uploaded into MAPINFO.

19. The county uses a database software package that is incompatible with MAPINFO. At our request, the county data was reformatted to an ASCII file. The students then loaded the database into MAPINFO.

20. The text of the resource guide is available at the following web site: URL http://cua6.csuohio.edu/~wendy/StCir/Title.htm.

21. Physicians finding elevated pediatric lead levels are required by federal law to report the finding to the public health department.

22. This research is based on a hypothesis that houses with conditions associated with elevated lead blood levels (age of structure, disrepair and old lead paint) may also be characterized by conditions associated with asthma (high levels of dust, roach feces, and mold). For additional information about this project, contact Mr. Stu Greenberg, Environmental Health Watch, 4115 Bridge Ave., Cleveland, OH 44113. (216)961-4646.

23. These authors cite numerous examples of university based and local and regional government based efforts to broaden access to data. For example, they describe data access projects such as the NeighborLINE sponsored by the Carnegie Library in Pittsburgh, Census Analysis Project in Minneapolis-St. Paul, and the Cleveland Area Network for Data and organizing at Case Western Reserve University. However, these projects focus primarily on social data. An interesting example of online data access is the RLIS Lite project by the Metro Portland Government, which provides environmental data for the region URL http://www/metro.dst.or.us/metro/drc/data_dic/datadic.htm. Another example is Neighborhoodlink in Cleveland, which provides several dozen public Internet access points throughout the city at public libraries and community centers. URL http://little.nhlink.net/nhlink/.

24. Above all, any data assistance efforts by universities or other intermediary organizations must also include information that will make the project sustainable. University projects must transfer information regarding where and how the data was retrieved, a contact person for future data needs, and how to access the data as part of the assistance efforts. The objective is to transform the knowledge of CBOs to more effectively access data after the university project goes away.

25. For example, our efforts to map TRI and air discharge data reveals a serious challenge to GIS utility for environmental pollution when used by organizations at the neighborhood scale. Pollution data is collected by agencies and organized according to a set of identifies which most often entailed both the street address and an agency provided facility identity number. Because we knew the location of many of the company facilities in the neighborhood, we discovered that the street addresses given in the data bases were corporate headquarters, not the address of the facility itself, making difficult the use of parcel maps to explore relationships between discharge points and residents. In addition, facilities sometime span many lots in a neighborhood, so the street address of the facility tells one little about the actual location of the discharge point. Based on these experiences, we recommend that USEPA and its state

and local agency administrative partners require that TRI reporting facilities include the assessor's parcel number for each emission point in their reporting. Such an identifier would immediately locate each emission or release point to a more specific location, something highly desirable at the neighborhood scale.

26. The NEOEDEN Web site can be accessed at the following URL: http://urban.csuohio.edu/~ucweb/neoeden/index.htm

27. See Sawicki & Craig, 1996, Appendix A; two examples cited of technical support programs beyond data provision by intermediary, non-profit organizations include the Neighborhood Data Center of the Milwaukee Associates for Urban Development and the Neighborhood Partners Data Service, also in the Milwaukee area.

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Wong, David. 1993. "A Spatial Decision Support System Approach to Evaluate the Efficiency of a Meals-On-Wheels Program." Professional Geographer Vol. 45 (3) : 332-341.Figure 1. St. Clair-Superior Neighborhood in the City of Cleveland, Ohio

A Risk-Based Approach to Assessing the 'Fitness for Use' of Spatial Data

Aggrey Agumya and Gary J. Hunter

Abstract: *In this paper the authors propose an alternative method for assessing the 'fitness for use' of spatial data. While the traditional standards-based approach to this problem has long been used (due primarily to the map production roots of spatial data handling), the authors believe this method has several limitations. As an alternative they propose a technique based on risk management practices, in which a study is made of the effect that uncertainty in the data has upon the ultimate decision to be made with it. In turn the adverse consequences of making a poor decision are quantified, and it is this information which enables a user to determine whether a data set is fit for use or not. The paper presents a six-step risk management process which includes a variety of options for reducing the risk that an agency may face when using spatial data for critical decision making. Finally, an example is provided which illustrates the entire process.*

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1. Introduction

This paper proposes an alternative approach to the traditional method of assessing the 'fitness for use' of spatial data. It begins by examining the shortcomings of the traditional standards-based approach and explains how an alternative option that focuses on assessing the impact or consequences of uncertainty may be more appropriate. The suggested method not only overcomes several limitations of the standards-based technique, but also offers mechanisms for managing the impact of uncertainty in data that is eventually accepted for use. It is argued that this latter feature is an important characteristic of the proposed approach because the problem of uncertainty neither ends with nor is limited to simply assessing fitness for use. Hence it is desirable that any fitness assessment provides significant inputs to the subsequent uncertainty management steps.

Furthermore, in those cases where conditions, traditions or the circumstances of users and their access to data preclude assessment of its fitness, a knowledge of how data uncertainty affects their decisions is essential for managing the possible consequences of uncertainty. The suggested method uses risk as a metaphor for quantifying the consequences that uncertainty in data may have upon the decisions for which it is used. The paper discusses limitations of the standards-based approach, then reviews the concept of risk, its subjective bias, and the factors that influence its perception. Finally, the paper outlines the risk management process for assessing fitness for use, presents an example of its application, and discusses the limitations of the approach and future research issues that will need to be resolved.

2. Limitations of The Standards-based Approach

The primary concern that end-users have about uncertainty in data is its potential impact upon their decisions. As such, the assessment of fitness for use is intended to avoid using data whose uncertainty is associated with consequences that are deemed unacceptable. Therefore fitness for use is essentially about, and should be ultimately determined by, whether the impact of uncertainty is either acceptable or unacceptable. The method traditionally employed to assess fitness for use — the standards-based method — compares data uncertainty with a set of standards that reflect acceptable levels of uncertainty in the data (Frank 1998). With this technique, fitness for use is assessed by directly comparing the quality elements of information against a set of standards that represent the corresponding acceptable quality components. To facilitate direct compari-

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son, the standards are defined using the same elements as those used for describing data quality. These may include: scale (of the source document); Root Mean Square Error (RMSE); resolution; Percentage of Correctly Classified pixels (PCC); currency; and percentage completeness.

Its use as the method of choice for assessing fitness can be traced back to the map production roots of spatial data handling, where positional and attribute accuracy standards have long been used for quality control and assurance. Since uncertainty in the data is considered to be acceptable if its consequences are acceptable, then the standards approach inherently reflects a certain threshold of acceptability. However, the standards-based method does not provide for estimation of the consequences of uncertainty and it is argued that this is one of its key limitations.

While uncertainty in spatial data is composed of several well-known elements (Guptill and Morrison 1995), the obvious measurable ones are positional and attribute accuracy, logical consistency, completeness and currency. Unfortunately, measures of these elements cannot as yet be combined into a single meaningful composite index (Veregin and Hargitai 1995), which means that assessment of fitness for use entails inspecting each element separately. In turn, this requires specification of a separate standard for each element, and the necessary standards are derived by inverting the acceptable consequences of uncertainty into a set of the various elements of spatial data uncertainty (Frank 1998).

This inversion is perhaps the most vexed problem of the standards-based method, since it involves estimating several unknowns from a single value — a problem without a unique solution (since the solution is an infinite number of possible combinations of the unknowns). This makes the use of simplifying assumptions imperative — for example the standard may be based on a single uncertainty element to which all consequences will be attributed. The uncertainty element typically assigned this role is the one to which the decision is most sensitive, but clearly such assumptions compromise the validity of the estimated standards and ultimately the fitness for use assessment.

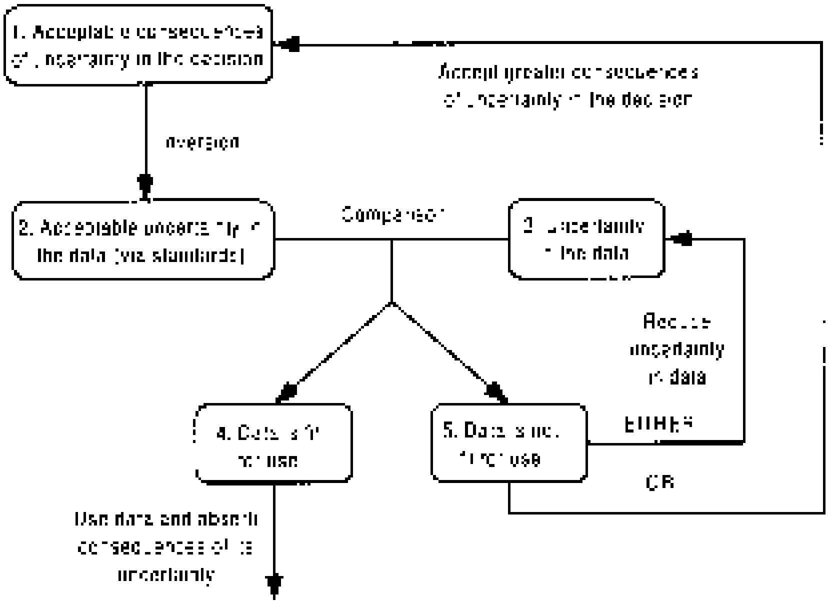
Assessment of the various uncertainty elements separately, according to a limited combination of standards, fails to account for possible trade-offs and compensations that occur when the elements are combined. For example, uncertainty in slope gradient is primarily influenced by the positional and attribute accuracy of elevation models. Using the standards-based method, a dataset is declared to be unsuitable if either its positional or attribute accuracy does not meet a specified standard, but this assessment does not take into account the fact that when considered jointly the two accuracies may well produce a result that is acceptable. In another example, it was rumored in the mid-1990s that an Australian emergency service agency was to take out a $20 million insurance policy to protect itself against liability claims arising from its use of a GIS-based dispatch system. While the street centerline and address databases were produced according to contract specifications (standards), the authors suggest there was no means of separating out the individual error effects of poor positional accuracy (of the street segments), attribute accuracy (street numbers and names), logical consistency (street network topology), completeness (missing street segments and addresses) or currency (out-of-date information), and as such the $20 million figure may well have been simply a calculated guess. Instead, with a risk-based approach it would have been possible to determine which of these factors contributed most to the potential liability associated with the system and to formulate a strategy for reducing this liability in the most cost-effective manner.

Furthermore, the reluctance by many users to formally assess the fitness of their data can be traced back to the difficulty of the task (Beard 1997), and the failure of the method of assessment to rationally justify the undertaking primarily because it does not warn users of the consequences of uncertainty. As Goodchild (1998) observes, politicians and decision makers often ignore uncertainty issues because uncertainty is not portrayed as a number to which they can easily relate. The authors agree with this contention and suggest that a more appropriate form which users would relate to more easily and effectively, is one that they associate with the consequences of uncertainty such as liability, pecuniary losses and mortality.

At the same time, there are instances when users are constrained to use particular datasets regardless of the uncertainty they contain because alternative datasets either do not exist, are not accessible or not feasible to use. For example, it is simply not feasible for a person or organization other than a national statistical agency to undertake a national census, and so users are constrained to use the data that is officially available. For users faced with these conditions the main concern regarding data uncertainty should be managing its impact on their decisions. This is also a concern shared by those who already assess fitness, because they too must eventually absorb any residual uncertainty and therefore need suitable mechanisms for managing its impact. Because the standards-based approach does not involve estimating the size of the impact of uncertainty, it offers limited value for managing uncertainty. In addition, the inability of the method to enable comparison between competing datasets that are all judged suitable, diminishes its usefulness when the problem extends to choosing the best among several suitable datasets.

From Figure 1, when a fitness assessment establishes that a dataset is unsuitable the initial reaction is to reduce uncertainty in the data. However other options exist such as accepting higher consequences of uncertainty and thus tolerating greater uncertainty, or reducing the vulnerability of the decision to uncertainty in the data by diminishing the influence that it exerts upon the decision. If acceptance

Figure 1: The standards-based approach to assessing fitness for use.



of higher consequences is chosen, then again the key issue is quantifying the extra burden of the consequences. The third option of reducing the vulnerability of the decision involves establishing an association between reduction of the influence of data on a decision and the resultant reduction in the consequences of its uncertainty. Again, the standards-based approach is not well suited to supporting this method. Quantifying the consequences of uncertainty is also necessary for stimulating interest amongst those that ignore the issue because they remain doubtful as to its impact upon their decisions. Furthermore, quantification can provide a compelling rationale to system managers for supporting further system development and implementation, by helping to determine the ratio between the cost of avoided misuse achieved by using suitable data, and the required funding.

Thus, the fundamental shortcomings of the standards-based method revolve around the fact that it does not involve quantitative estimation of the consequences of uncertainty. Knowledge of these consequences is essential for improving the utility of spatial data and motivating reluctant users who may be exposed to potential losses to undertake fitness assessments. Such knowledge is also necessary for managing the consequences, and accordingly the authors believe an alternative approach to the current standards-based method is required.

3. An Overview of The Risk-based Approach

Risk analysis has already been suggested as a plausible basis for characterizing and estimating consequences of uncertainty in spatial data (Goodchild 1992). Using risk to represent the consequences of uncertainty has the added benefit of being amenable to an established framework (risk management) for estimating and managing the consequences of uncertainty. In recognition of the limitations of relying on standards and of the potential benefits of a risk-based approach, the transition from standards has already been proposed by organizations such as the water resources planning and management division of the American Society of Civil Engineers (Haimes and Stakhiv 1986), the Australian National Commission On Large Dams (ANCOLD) (McDonald 1995), and the US Environmental Protection Agency (The Conservation Foundation 1985). According to the risk-based approach (Figure 2), assessment of fitness for use essentially involves establishing whether the adverse consequences of uncertainty in the data, expressed in terms of risk, are acceptable or not. The assessment process therefore elicits answers to two fundamental questions, viz.:

- What are the adverse consequences associated with the decision, in terms of risk, attributable to uncertainty in the data? and
- What are the acceptable consequences of uncertainty in terms of risk?

Answering the first question entails propagating data uncertainty, in its various elements, into risk. The propagation demands an understanding of how uncertainty in data interacts with the decision environment to adversely affect decisions, and the extent to which a particular dataset influences decisions — that is, the degree of utilization of the data (Zwart, 1991). If the utilization of data in a decision is minimal, such as when it is only referred to, then it is reasonable to expect uncertainty in that data to have a lesser impact in terms of risk than if the utilization was more significant, such as when the data has the power to change decisions. Indeed, when uncertainty in data is very high it is common for users to minimize their exposure to its impact by limiting the utilization of the data (Laws et al. 1989)

The second question entails establishing a threshold for the risk that is considered acceptable. Here, the word ‘acceptable’ prompts the crucial questions: ‘acceptable to who, in whose view and in what terms?’ (Lowrance 1976). These questions point to important characteristics of the risk threshold, and consequently of fitness for use, namely that the threshold is subjective and influenced by continually changing values (economic or other means), the constraints of parties to the risk, and the circumstances under which the risk is determined (Fischhoff *et al.* 1981). Each of these factors depends on the context of the decision and are subject to change over time. In turn, users may be categorized into two groups according to how they respond to uncertainty in data, viz.:

- those who establish the fitness of data before using it; and
- those who use data regardless of its fitness, either because they are compelled to use it or else they choose to ignore its uncertainty.

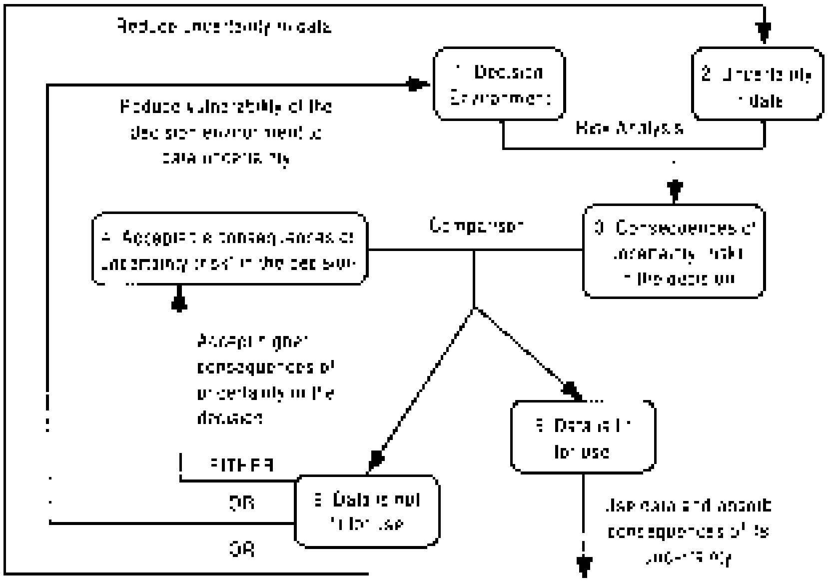
Because the risk-based approach provides for estimating consequences of uncertainty, its relevance extends even to those users who choose not to test data for fitness. For data that are judged to be unsuitable, the risk-based approach offers several possible actions (as in Figure 2) all of which are quite practicable. They include reducing the uncertainty, accepting more risk, making the decision environment less vulnerable to uncertainty in data, or any combination of the above. This range of options is a feature of the risk-based method that makes it more favorable than its standards-based counterpart.

Smith *et al.* (1991) and Burrough *et al.* (1996) show that the quality of information is a function of both the quality of the models (or algorithms) and the data used to derive the information. For unstructured decision problems the models are less well known, rendering the propagation of data uncertainty into risk more difficult. Furthermore, in such decisions the contribution of data uncertainty to the overall decision risk is likely to be less significant compared to the risk attributable to uncertainty in the models, which is largely unknown. Finally, the lack of decision structure implies that a single dataset is not likely to determine the decision, so in general the degree of utilization for individual datasets is low. For these reasons, the risk-based approach is not well-suited to unstructured problems.

4. The Concept of Risk

Risk is an abstract parameter for representing the impact of adverse events or actions about which there is no certainty (Thomson 1987). It is an important factor in decision making since it is one of the few quantitative variables that can determine the utility of decision alternatives. It consequently aids in providing a rational basis for comparing not only those alternatives, but also for allocating

Figure 2: *The risk-based approach to assessing fitness for use of spatial data.*



resources towards risk reduction and improving safety and public health (Starr 1987). Analysis or estimation of risk entails identifying the potential damage, injury or loss associated with events or undertakings, and estimating its likelihood. This knowledge is then used to determine the level of exposure and to judge whether the risk is tolerable or unacceptable (Fischhoff *et al.* 1981, Bohnenblust and Schneider 1987). Understanding the process and degree of exposure is essential for developing mechanisms, safeguards and responses for limiting the likelihood and/or magnitude of damage as well as the cost of the damage (Rasmussen 1981, Starr 1987). Indeed, as Reid (1992) points out, quite often simply understanding the process of exposure can be more useful and informative than deriving the ultimate quantitative values of risk.

4.1 Definition of Risk

'Risk' is a very overloaded term. It cuts across many disciplines and although it has been extensively discussed, it still lacks a standard definition. Fischhoff *et al.* (1984) suggest that the definition of risk is inherently controversial because of the important role that risk plays in policy issues. They point out that the choice of definition can depend on how well it suits particular policy positions and as such is an inherently political issue. However, there is general agreement that the notion of risk involves uncertainty about occurrences or outcomes of events, which are associated with some kind of loss or damage (Kaplan and Garrick 1981, Gratt 1987 and Williams 1995). Sage (1995) on the other hand, argues that risk is not limited just to adverse events but includes positive outcomes as long as their occurrence is uncertain. This interpretation is common in insurance and economics applications and is referred to as 'speculative risk'. Nevertheless, the sense in which the term risk is traditionally used is the one that connotes the possibility of loss or damage rather than gain. This does not necessarily mean that any undesirable event or outcome of a decision constitutes a risk, but rather that it only becomes a risk when there is uncertainty about its occurrence. In addition, there are some terms that are often erroneously used as synonyms for risk, the commonest examples being uncertainty and hazard.

4.2 Risk Versus Uncertainty

'Risk' and 'uncertainty' are so inextricably related that they are often used interchangeably especially in the disciplines of economics, insurance and heath science. For example, Knight (1921) defines risk as 'measurable uncertainty' while others variously describe it as 'the uncertainty of loss' or 'the objectified uncertainty regarding the occurrence of an undesirable event'. Nevertheless, decisions are said to be made under conditions of risk when the likelihood of their outcomes is known, whereas they are made under conditions of uncertainty when the likelihood of their outcomes is not known (Davis and Olson 1985). The predominantly held view, sometimes referred to as the engineering view, defines risk as a function of uncertainty or likelihood about the occurrence of an event that occasions loss, and the loss suffered if the event occurs. Some authors decline to specify the structure of the relationship between the two parameters (likelihood and loss), however many such as Gratt (1987), Raftery (1994) and Williams (1995) characterize risk as likelihood multiplied by loss. The 'likelihood times loss' characterization of risk depicts it as a single valued measure, and while this is desirable for comparing risks it can mask valuable information about the joint variability of likelihood and loss. Knowledge of this variability is important for understanding how the contribution to risk is distributed, which in turn aids in establishing where to best target risk reduction and other risk response efforts.

4.3 Risk versus Hazard

Another term that is closely associated with and sometimes confused with risk is 'hazard'. Kaplan and Garrick (1981) define a hazard as the source of adverse consequences, while from a social science viewpoint Pidgeon *et al.* (1992:89) define it as '… threats to people and the things they value'. From these perspectives, it can be argued that exposure to risk results from the presence of a hazard. It can hence be asserted that uncertainty in spatial information may constitute a hazard, especially if it is ignored. In seismology a hazard is the likelihood of an area being affected by potentially destructive seismic activity within a given period of time. Seismic risk is a function of (seismic) hazard, value and vulnerability, where value includes the number of people or amount of property exposed to the activity, while vulnerability is a measure of the proportion of value likely to be lost or damaged by the activity (Dobran 1995). In this paper the word 'hazard' will be used in an engineering sense, that is, it will refer to causes of adverse consequences.

4.4 Real versus Perceived Risk

The notion of real risk is controversial. Elms (1992) describes it as the risk that would be calculated if all the relevant information about the likelihood and consequences of an adverse event were known. This suggests that the difference between perceived and real risk lies in the completeness and certainty of knowledge about the likelihood and consequences. Kaplan and Garrick (1981) assert that the notion of real risk or absolute risk always ends up being somebody else's perceived risk. Hence the conflict between real and perceived risk can be thought of as conflict between risk perceptions of experts and those of the public. The expert's concept of risk is based on a narrow definition of risk which is limited to the likelihood and undesirable consequences of an event, whereas the public's conception of risk is much broader and includes a host of attitudes towards the event (Kasperson *et al.* 1988). The perception of risk involves the beliefs, judgements, feelings and values that people adopt towards adverse events (Pidgeon *et al.* 1992). These psychological, social and cultural preferences influence attitude to risk as well as acceptance and the acceptable level of risk. Hence they should be considered when making decisions that affect the public. The various characteristics upon which risk perception depends have been widely discussed, (Lowrance 1976, Rowe 1977 and Elms 1992), and include:

- Voluntariness of the risk: people are more averse to adverse events that they have no control over. In most cases, this is the characteristic that has greatest influence on perception of risk.
- Familiarity with the event or its consequences: familiarity tends to reduce the perceived risk.
- Extent of damage or loss: reaction to a single disaster that leads to monumental loss tends to be much stronger than that of a similar loss, which is scattered over several events. Hence risk due to the former is perceived to be greater.
- Cultural context: culture which shapes people's values, beliefs and their attitudes to loss in turn biases their perception of risk due to particular events;
- Personal context: the relative vulnerability of the public to consequences of an event amplifies its perceived risk, while its importance and anticipated benefits diminish its perceived risk.
- Nature of communication: when descriptive communication of adverse events emphasizes consequences at the expense of benefits, it increases their perceived risk and vice versa.
- Long-term versus short-term exposure: long term exposure is considered to be more serious than short-term exposure because the risk has to be lived with all the time. Hence risks associated with the former are perceived to be greater.
- Immediacy of consequences: there is greater aversion to events with consequences that are immediate than to those that manifest themselves at a later time.
- Availability of alternatives: risk associated with situations for which there are no practical alternatives is perceived more favorably than where alternatives exist.
- Reversibility of consequences: irreversibility of consequences tends to amplify the perceived risk and vice-versa.
- Whether exposure is essential: when exposure is necessary, such as in medical treatment, the risk is perceived more favorably than when the exposure is a luxury.
- Certainty with which risk is known: the natural aversion towards events with risks that are not well understood amplifies their perceived risk.

It is evident from the foregoing discussion that the questions: "Who is perceiving the risk?" and "Why they are perceiving it?" are very important. Therefore, analyses of risk due to uncertainty in spatial data should consider and specify the parties affected by the consequences of the uncertainty and accordingly account for their perception of risk. Such specification will determine the scope for use of the risk information, that is, whether it is relevant only to the user or to the broader community as well.

5. Quantitative Evaluation of Risk

Typically, an adverse event has multiple scenarios each with a corresponding likelihood and loss. Therefore a risk analysis entails asking the following three questions:

- What can happen or what can go wrong? (defining the scenario)
- How likely is it to happen? (estimating the likelihood)
- If it does happen, what are the consequences or losses? (estimating the impact)

Unfortunately, there are no neat mathematical relationships to assist risk analysis that can satisfactorily define the relationships between all possible scenarios, their likelihoods and their consequences. Instead, the typical approach is to arrange the different scenarios in order of increasing severity and then plotting the consequences against their cumulative likelihood. Smoothing the resulting staircase function produces a risk curve (Figure 3), which is the preferred portrayal for many types of risk such as those due to natural hazards, pollution and engineering structure failures (Starr 1965, McDonald 1995).

As noted earlier, the definition of risk as likelihood times consequences enables its quantification, which in turn aids comparison. However, the aggregation of likelihood and consequences into a single metric leads to loss of information and has been described by Rasmussen (1981) and Schneider (1987) as simplistic. The main complaint with this characterization of risk is that it equates low-likelihood and high-consequence scenarios with high-probability and low-consequence ones. To overcome this issue, alternative methods may be used which involve placing different weights on the consequences according to their unacceptability in the context of the decision to be made. Nonetheless, the simple multiplication of likelihood by consequences is effective in many cases, and this value in turn is multiplied by the degree of utility of the data used in the decision (with the utility value varying between zero and one).

Of course, the estimation of risk itself is subject to uncertainty for the following reasons:

- simplicity in the definition of risk;
- inevitability of subjective judgements in the analysis of risk;

- uncertainty in estimates of likelihood, consequences and any other variables (such as value of life) that may be used in estimating risk;
- poor identification of scenarios and their ranges; and
- the inability to exhaust all possible scenarios, including the inclination to focus on scenarios that are amenable to quantification at the expense of those that are not, which leads to underestimation of risk.

The main problem with uncertainty in risk estimates is not that it exists, but rather whether its magnitude is known and reported. Okrent (1982) warns that it is essential for risk analyses to provide statements of assumptions made in arriving at values used in the analysis and to point out any known uncertainties in the risk estimates. Evidently the same reasons used to argue for reporting uncertainty in spatial data under the concept of "truth in labeling", also apply to reporting uncertainty associated with risk estimates. It is clear that satisfactorily accounting for all sources and quantifying the uncertainty in risk is an elusive goal. In order to estimate the uncertainty associated with risk due to uncertainty in spatial data, meta-uncertainty of the data as well as the uncertainty associated with estimates of consequence scenarios are necessary. Unfortunately, this data is often not available.

Having identified the different adverse event scenarios, a risk analysis proceeds to estimate their likelihoods and consequences. Analysis of risk due to uncertainty in spatial data requires two sets of information:

- a report on uncertainty in the spatial data (data quality report); and
- the relationship between the magnitude of uncertainty and consequences, which is used to estimate the consequences of each scenario.

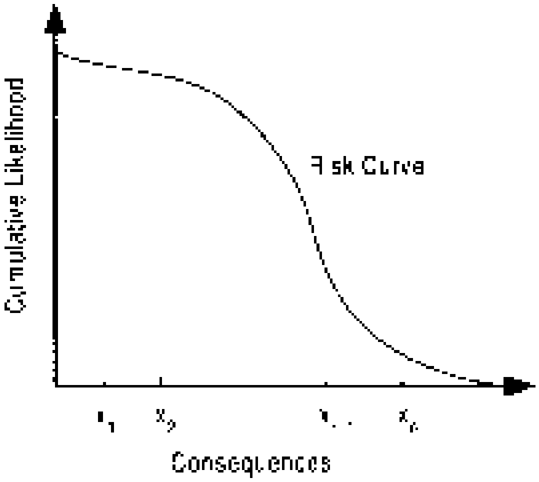
This shows that likelihood is the risk parameter directly associated with uncertainty in data, and that a typical data quality report provides only part of the information necessary for risk analysis. Probability, in the widest sense of the term, is invariably used as the measure of likelihood when estimating risk. Accordingly, the preferred representation of uncertainty is in probabilistic terms. However, not all types of spatial data uncertainty are modeled on probability theory. (Shi 1995) and Stoms (1987) categorize uncertainty in spatial data into three classes according to the theories suitable for modeling them. They include:

- uncertainties due to randomness or variability of error;
- incompleteness of evidence, such as when sampling has been applied or surrogate variables employed; and
- vagueness, which may result due to imprecision in taxonomic definitions.

Theories appropriate for modeling these uncertainties include: probability theory, Dempster-Shafer's theory of evidence and fuzzy set theory. Probability theory, which has a rigorous foundation, enjoys a long tradition dating as far back as the 17th century whereas Dempster-Shafer's theory and fuzzy set theory are relatively recent (introduced in 1967 and 1965 respectively). The Dempster-Shafer theory, or the mathematical theory of evidence, recognizes the existence of ambiguity or ignorance due to incomplete information. The absence of evidence to support a hypothesis is not assumed to constitute evidence against it. This means that what is known and what is not known are explicitly evaluated. The theory is based on complementary measures, namely *belief* and *plausibility*, and the interval between them¾*belief interval*. The scarcity of reports documenting application of the theory in GIS suggests that it has not yet attracted widespread use. However, some of the reported applications show that it has been applied in the classification of multi-spectral scanner data (Lee *et al.* 1987) and in a GIS application for finding optimal routes for military helicopters (Garvey 1987). In recognition of the importance of this theory in modeling uncertainty due to incomplete evidence (information), appropriate classifiers are now supported in recent versions of some software products such as IDRISI.

Fuzzy set theory was introduced by Zadeh (1965) to handle vague or imprecise concepts in a precise fashion that a computer can handle. It allows partial membership in a set and its basis lies in the assignment of a membership function which indicates the degree to which an observation, X, belongs to a set, A. The membership function may also be viewed as the measure of belief that X is an element of A, or as an index of the relative accuracy associated with assigning observation X to class A. Membership function values (membership grades) are real numbers ranging from zero to one, where values closer to one indicate full membership and those close to zero indicate non-membership. The vagueness modeled by fuzzy set theory pertains to definitions of classes (or sets) into which objects or phenomena are to be assigned. The boundaries of these classes are gradual such that membership grades of objects gradually transition from non-membership to full membership. On the other hand probability theory is based on classes that are crisp such that objects either wholly belong a class or they do not. Fuzzy sets are increasingly being used in remote sensing for image interpretation and classification, and the results have been shown to be useful in extracting more information than with conventional approaches based on crisp sets (Gopal and Woodcock 1994). They have also been applied in GIS to represent uncertainty and propagate it as data are transformed by various GIS functions (Veregin 1989).

Figure 3. *The risk curve showing the cumulative likelihood for the consequences for each adverse event scenario as a result of data uncertainty.*



6. The Risk Management Process

The overall risk management process involves a series of tasks (Figure 4), viz.: risk identification; risk analysis; risk appraisal; risk exposure; risk assessment and risk response. Risk identification is considered to be the most important step in the process on the grounds that "a risk identified is a risk controlled". It essentially involves determining what may go wrong and how it may happen. Risk analysis requires estimating the probabilities and expected consequences for the identified risks. The consequences of an adverse event will vary depending on the magnitude of the event and the vulnerability of the elements affected by the event. The outcome of risk analysis is risk exposure. Risk exposure is the total amount of risk exposed by the adverse event, and can be considered to be the summation of all the individual risks identified. Risk appraisal involves determining the magnitude of risk which is considered acceptable. It can be determined by analyzing and choosing the risk associated with the most favorable among the possible combinations of decision quality indicators, namely cost-benefits and risks. A complication of this step is the difficulty in quantifying the intangible benefits of a decision. Risk assessment requires comparing risk exposure with the results of risk appraisal. Depending on whether the risk exposure is acceptable or not, the decision maker must then consider taking an appropriate risk response. Risk response is the final stage in the process and also the ultimate objective of risk management—to help the decision maker make a prudent response in advance of a problem. The possible responses to risk exposure include: avoidance, retention, transfer, control, and insurance.

By way of example, we can illustrate how the risk management process might be used to assess the fitness for use of a particular geographic data set. Consider a manager responsible for emergency response in a region who needs to know what land parcels and residents would be threatened by a particular magnitude flood event. In order to prepare the emergency response plan, a DEM of the region is considered to be a key data set in the manager's decision-making processes, and may be assumed to have the highest utilization factor possible. The manager wishes to establish the fitness for use of the DEM before basing the emergency management plan upon it. The data quality component that the manager is particularly concerned about is the accuracy of elevations, and the data quality statement that accompanied the DEM indicates that for elevation values it has a Root Mean Square Error (RMSE) of 7 metres.

Step 1 – Risk Identification: The manager starts by identifying what could go wrong due to error in the data and how it may happen. The possible adverse event arising from uncertainty in the DEM is where locations declared clear of flood waters in fact become inundated due to elevations in the DEM being greater than their true values on the ground.

Step 2 – Risk Analysis: The manager then examines the likelihood or probability of the adverse event and its possible consequences. In this case, residents of properties that have been incorrectly designated as not subject to flooding will have been led to believe they are safe and may not take precautionary measures. When the area is flooded, the agency responsible for emergency response could find itself subject to compensation claims for negligence which may have caused damage to property, loss of income and personal injury or loss of life. The probability of the adverse event occurring (that is, the flooding of areas declared to be safe) is equivalent to the probability of the elevations in the DEM being greater than the nominated flood level — when in fact they are not. The consequences of the adverse event then need to be quantified in appropriate units, for instance dollars, injuries or lives lost. The magnitude of the consequences will depend on the vulnerability of properties and residents to the adverse event; the values of the properties; and the magnitude of the event (in this case, the depth of inundation of the areas that were erroneously declared free from flooding). All three parameters might vary in space such that geographical analysis may need to be applied to account for local variations when estimating the value of the consequences.

Step 3 - Risk Exposure: From the two profiles constructed at the end of the risk analysis stage (that is, probability vs magnitude and magnitude vs vulnerability), the user can compute estimates of the risk exposure for each magnitude of adverse event (that is, for different inundation depths). The exposure is the summation of identified risks and may be expressed as a combination of diverse units depending on the nature of the consequences — for example, dollars, injuries sustained and lives lost.

Step 4 - Risk Appraisal: The manager then establishes how much risk is tolerable. For example, this might be the maximum amount of money that can be set aside or for which the agency is insured to compensate victims for the its negligence. Tolerance limits may also be set for other consequences such as lives lost and harm to the reputation of the agency. The procedure for determining these limits is discussed further in Agumya and Hunter (1998).

Step 5 - Risk Assessment: This step compares outcomes from the risk exposure and risk appraisal stages. If the risk exposure is less than or equal to the tolerable risk appraisal, then the DEM is fit for use. However, comparing the risk exposure and tolerable risk can be complicated by the different units in which risk exposure and appraisal are expressed. Table 1 illustrates how this difficulty may manifest itself, and the manager may have trouble deciding whether the risk exposure is less than the tolerable risk. For example, use of the DEM may yield a risk exposure of a single loss of life and property damage worth a million dollars, compared to a tolerable risk appraisal of no deaths and up to two million dollars damage. However, criteria do exist for aggregating risk in various units into a single unit, such as dollars. For example, the value for a lost life might be based on an estimate of the amount of money that the deceased would have earned during an average life expectancy. At this point, there will clearly be many factors that will impact on what is and is not tolerable with respect to the degree of error associated with the declaration of flood affected land.

If the risk exposure exceeds the acceptable risk appraisal, then the manager is faced with three options regarding the fitness for use of the DEM:

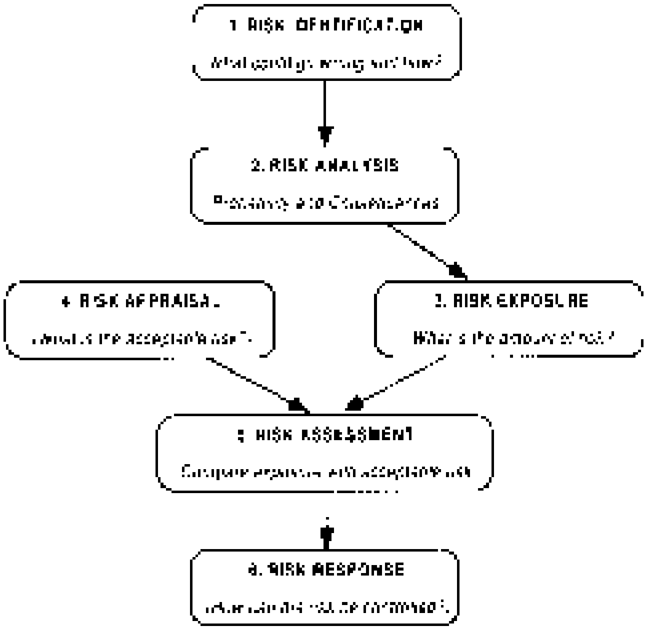
- reject it and secure another DEM of superior quality;
- retain the DEM but improve its quality; or
- use the DEM regardless of the consequences, since securing a superior data set or improving upon the quality of that available are not feasible options due to cost and/or time constraints.

At the end of the risk assessment stage the manager is aware of the uncertainty in terms of risk that the agency is being exposed to and will need to either reduce it or absorb (accept) it (Bedard, 1987). The manager may then use the knowledge gained about these risks to chose the best method of protection from their consequences.

Step 6 - Risk Response: Finally, a decision must be made regarding how to deal with the risk exposure. Again, there are several options available:

- **Risk Avoidance:** this is where the decision maker chooses to avoid the possibility of being exposed to risk. It is the ‘do nothing’ option, and in the DEM example above it is not available to the agency in question because risk avoidance would mean that the agency would have to cease carrying out its functions.
- **Risk Retention:** sometimes referred to as *risk assumption*. This is when the decision maker bears liability for either some or all of the consequences of an adverse event, either deliberately (active retention such as with a deductible in an insurance policy, or as in the case of some land title registries where the correctness of the information is guaranteed), or out of ignorance or indifference (passive retention). Retention is appropriate primarily for risks of low probability and relatively small consequences. In the example given, retention does not appear to be an appropriate choice because the consequences are likely to be relatively large.
- **Self Insurance:** another version of risk retention whereby parties faced with exposure to similar adverse events pool together their exposure in order to accurately predict the risks they will be exposed to. The difference between self insurance and other insurance operations is that the body underwriting the insurance is also part of the one it is insuring. The availability of this option depends on whether the agency has willing partners with whom to pool its exposure.
- **Risk transfer:** this is when the party exposed shifts the risk to another party, other than an insurance company. The transfer may be through a contract or a clause in an agreement or undertaking or through hedging (whereby the party exposed, the hedger, takes two simultaneous positions that offset each other so that no matter what the outcome of an adverse event, the hedger never loses or wins). If the agency in the example above were to respond to risk exposure by transfer, it could if possible secure legal liability protection, or transfer the risk to another government body. However, this may not be in the best interest of the reputation of the agency. Also the agency may be liable for such losses under statutory law.
- **Loss Control (prevention and reduction):** is concerned with reducing the probability of occurrence and consequences of an adverse before it occurs. In the example given, the probability of occurrence depends on the amount of uncertainty in the DEM. This uncertainty can be reduced where possible by purchasing a more accurate DEM or one with a higher resolution. The consequence is dependent on the vulnerability of the elements exposed, their value and the magnitude

Figure 4: The risk management process.



of the adverse event. The consequence can be reduced by taking precautionary measures in the most vulnerable areas such as where there is high population density, high property values and where property is in general vulnerable to damage by flooding. Loss prevention is only feasible as long as the benefits realized from the prevention are greater than the cost of the loss prevention program. Loss reduction is intended to diminish the consequences after the adverse event has occurred. Since for purposes of assessing fitness for use the user is particularly concerned with the risk posed by the adverse event before it occurs, this option is not relevant.

- **Insurance:** This represents a contractual transfer of risk from the party exposed, to an insurance company. Insurance is especially appropriate when the probability of occurrence of an adverse event is low and its consequences very high and is widely considered to be the most practical method of response to a major risk. Depending on the cost of the policy, it may be an attractive option for the user in this example (Epstein et al. 1998).

7. Limitations of The Approach and Further Research

Of course, the risk-based approach to quantifying and managing uncertainty in spatial data is not immune from problems and is itself subject to some degree of uncertainty. For instance, the assumptions employed may be open to challenge, and the perception and acceptance of the utility of risk management can be clouded when factors cannot be easily quantified in economic terms such as social issues, environmental damage and loss of life. Indeed, placing a value of the loss of life is one of the most vexing problems facing risk managers, and there are wide ranging views on how this should be performed. Furthermore, estimating the likelihood of events may be open to dispute, especially where it varies with location yet must be aggregated into simpler regional values. Risk analysis also requires special skills and can be an expensive to perform. Nevertheless, it is often noted that undertaking risk analysis can be extremely productive in itself and forces organizations to think deeply, often the first time, about the possible consequences of uncertainty in their data and its effect upon the decisions they make with it.

At this stage there are still several outstanding research issues that need to be resolved. The first is whether the proposed risk-based method is suitable for use with spatial data across a wide variety of applications. It may be that the approach is only viable for high-risk tasks such as in emergency response systems, in which case we need to identify (a) the threshold of its usefulness, (b) under what terms it becomes feasible to employ, and (c) whether it is suited for 'one-off' decisions that are rarely made. For other applications it should be determined whether the approach can be 'short circuited' in less important decision situations, yet still remain valid and resource effective.

8. Conclusion

In this paper an alternative approach to using standards for assessing the fitness for use of spatial data has been presented. The proposed risk-based method not only aids the assessment of fitness for use, but is also valuable to users for whom the primary concern about uncertainty in data is how to manage its impact. Risk management is widely used as a mechanism for dealing with consequences of uncertainty, however risk is a complex concept that must be radically simplified to make it quantifiable. Perception is an important characteristic of risk yet it is not easily measurable, and its subjectivity opens risk estimates to challenge. These factors combine to make risk estimates subjective, yet there is a tendency to believe that they are objective, especially considering that their determination often involves rigorous analysis. Nonetheless, risk has proven to be a very valuable tool for managing uncertainty in other disciplines and it is argued that further investigation of its potential for assessing the fitness for use of spatial data is now warranted.

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Table 1. *The Problem of Comparing Risk Exposure and Appraisal*

Consequence	Exposure	Appraisal
Loss of lives	1	0
Injuries (severe)	0	5
Property damage	$1 million	$2 million

lian Research Council Small Grant No. S499692, "Development of Risk Management Techniques for Handling Uncertainty in Spatial Information".

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Measuring Similarities of Spatial Datasets

Douglas M. Flewelling

Abstract:*The rapidly increasing availability of digital spatial datasets through on-line media generates a new demand for assessing and comparing spatial datasets with computational tools. Current geographic database systems are tailored to retrieving configurations based on the spatial relations among individual entities. Such one-by-one measures, however, do not scale-up, neither computationally nor cognitively, when applied to entire datasets within digital libraries or data warehouses. A particular challenge for users of the Internet is to find spatial datasets that are similar to a given dataset. To enable the comparison of spatial datasets, new computational measures are needed. We discuss the required properties of such spatial similarity measures based on their adherence to rules for deductive databases.*

1. Introduction

The World-Wide Web as operational in the late 1990s is strongly text-based, with search engines supporting the retrieval of documents based on the frequency of keywords. Finding spatial datasets does not fit into this setting, because it makes little sense to search for or compare strings of coordinates in order to match a spatial target configuration with spatial datasets that are available on-line. The addition of metadata, often promoted as the mechanism essential to select the right datasets, moves what should be a spatial search into the domain of textual keywords. While metadata may provide ways to describe datasets concisely, they are often subjective descriptors given by a data provider that may not necessarily fit the various needs of the data users (Flewelling and Egenhofer 1999). In order to enable the design of new search engines that would take into consideration spatial criteria, it is necessary to gain a better understanding of how to assess analytically differences among spatial datasets.

This paper is concerned with the comparison of spatial datasets that are assumed to share common elements such that there is a direct mapping between objects in the sets. While some of the measures presented here could be used to compare sets with different types of elements, it is beyond the focus of this research. In order to assess similarity it is necessary to perform a difference operation over the set attribute measures for each pair of spatial datasets. The ability to assess similarity will provide significant advantages in searching very large data collections from multiple sources, such as data warehouses (Garcia-Molina *et al.* 1995) and digital libraries (Smith 1996), where the likelihood of finding equivalence to a query is low.

The development of computational methods for the assessment of spatial-set similarity differs from approaches that are based on the comparison of individual objects. Algorithms to retrieve objects with similar shapes (Mehrotra and Gray 1995) or similar spatial relations between lines (Gudivada and Raghavan 1995) or objects (Bruns and Egenhofer 1996) are tailored to extracting individuals or pairs of individuals from a spatial dataset. In computer vision and image processing, content-based image retrieval relies on similarity measures that represent histograms of representative values of spectral values (Flickner *et al.* 1995; Faloutsos *et al.* 1994). On the other hand, geographers have for a long time investigated methods to describe similarity of point sets for spatial analyses, addressing such properties as pattern, density, and dispersion (Unwin 1981).

This paper continues with definitions of a model for spatial objects, spatial sets, and their respective attributes (Section 2). In Section 3 a model for comparing spatial datasets through similarity, equivalence, and identity is defined. Section 4 discusses the classes of content in spatial datasets. Section 5 investigates scales of data and the limits those scales have on analysis of set attributes. It continues to define formal methods for assessing similarity for all the data measurement scales. A formal approach to the combination of individual similarity measures into a single *simi-*

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larity index value is defined. The similarity index can be used for evaluating set similarity among three or more spatial datasets. Finally, the requirements for appropriate spatial measures as defined by the model presented here are summarized in Section 6.

2. A Model of Spatial Datasets

In order to compare spatial datasets, it is necessary to define a limited number of terms that form the components of a model of spatial datasets. In their work on types and data abstractions, Cardelli and Wegner (1985) laid out a terminology for sets and types. We expand on their definitions to introduce four key concepts for comparing spatial datasets: spatial object, spatial class, spatial set, and spatial ideal.

2.1 Spatial Objects

In the domain of geography, scientists are concerned with instances of *spatial objects*. Spatial objects are things with an identity and identifiable characteristics, among which is location. Some spatial objects are tangible things, such as trees or buildings, while others are concepts such as counties or sales districts. Spatial objects, such as buildings, can be aggregates of other spatial objects (doors, windows, walls), but the atomic spatial objects in the domain of geography are those large enough to be observable by the human eye and smaller than planetary scale. These bounds exclude both the microscopic and the astronomic (Mark and Freundschuh 1995).

2.2 Spatial Classes

People have developed a set of cognitive processes that reduce the complexity of an unstructured world. From a very early age people begin to develop *schemata* for the important parts of our world (Pinker 1990a; Johnson 1987; Eastman 1985; Neisser 1976). These schemata or *class definitions* provide structures upon which to organize the phenomena they observe and form the basis of the *classification* of spatial objects. For instance, a class definition for trees might include: location, has_woody_trunk, can_burn, has_leaves, and has_branches. A book would satisfy three of the functions, but not the others and is, therefore, not a tree. A spatial class has a class definition that supports, among others, the *location* function.

Spatial classes may restrict the range of values that may apply to a particular class of spatial objects. When a class supports all of the functions of another class, but is more restrictive on values or adds other functions, we call it a *subclass*. While a pine tree is certainly a tree, the needles and cones make it clearly a conifer rather than a deciduous tree. All functions of the superclass must be supported by a subclass, but subclass definitions need not be mutually exclusive (Smith and Smith 1977). For instance, a spatial object in the Building class could also be a member of both the subclasses *home* and *office*.

A particular object may be classified into more than one class depending on the attribute values it possesses. Within limited domains it is possible to construct hierarchies of classes that exclusively classify a group of objects. These *taxonomies* provide rules to classify any individual into an indivisible group. The applicability of a taxonomy is limited to a specific user group. For instance, while a particular stand of trees might be classified as a *mixed-growth habitat* by a forester, a child may classify the same stand of trees as a *playground*.

2.3 Spatial Sets

If we gather all the spatial objects of interest together we have defined a geographic universe for our problem domain. In this paper, this universe of spatial objects is denoted as G. In the universe G it is possible to create groups of spatial objects, called *spatial sets*, by collecting one or more spatial objects together and identifying them with a symbol or name. For instance, the Eiffel Tower, Moosehead Lake, and a maple tree are elements of a spatial set called Green. A spatial set does not have to have specific rules of membership, however, without membership rules a very large, but finite number of sets could be generated within G.

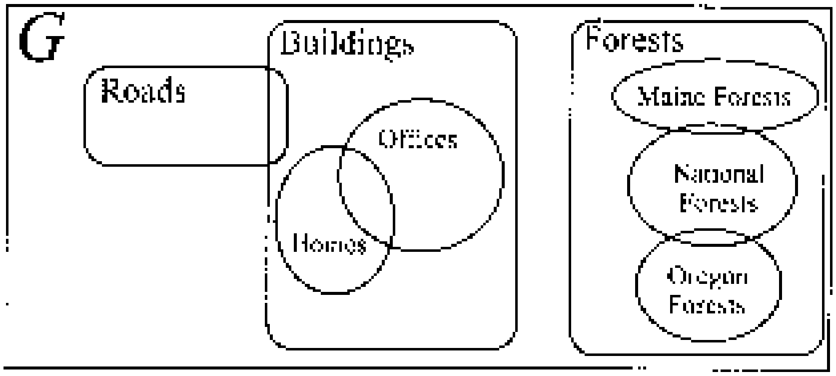
Creating a personal classification of the world with one's own symbols is of limited use. Fortunately, within a given culture people share class definitions with others and negotiate a common symbol set, which we call a language (Pinker 1990b; Zurif 1990). With a language, the connection between the symbol and the class is taught through a variety of means including example, simile, and in limited cases complete enumeration (Lakoff 1988; Johnson 1987).

2.4 Spatial Ideals

If all elements of a spatial set satisfy a specific class definition the set is called a *spatial ideal*. A spatial ideal does not necessarily contain *all* the instances in G that match the class definition. Therefore, any number of spatial ideals could share the same spatial class definition. The spatial ideal that contains all the spatial objects of that class is called the *universal spatial ideal* for that class. In Figure 1, the universal spatial ideal *forests* contains all the forests in G. The spatial ideals *Maine forests* and *Oregon forests* are both subclasses of *forests*, which have a spatial restriction in their respective class definitions. For practical purposes, it is often impossible to completely populate a universal spatial ideal with *all* the spatial objects that match a specific class definition. Without the universal spatial ideal fully populated it is impossible to reason absolutely about the objects in the ideal.

Gallaire et al. (1984) identified three basic assumptions upon which deductive reasoning in databases depend: (1) the closed world assumption, (2) the unique name assumption, and (3) the domain closure assumption. The *closed world*

Figure 1: *Spatial ideals and universal spatial ideals (Roads, Buildings and Forests). All spatial objects in a spatial ideal share a single class definition, but spatial ideals are not necessarily mutually exclusive.*



assumption states that facts that are not known to be true are assumed to be false. This assumption is required to support the use of Boolean logic in database systems. The *unique name assumption* states that objects with different names are different. This assumption is necessary to support uniqueness for entities in a database system. Finally, the *domain closure assumption* states that there are no other entities than those in the database. Without this assumption nothing definitive could be stated about the contents of the database because other objects might be found to invalidate the information derived from the database.

In practical terms, a spatial database system that operates with the domain closure assumption is working with universal spatial ideals. The use of universal spatial ideals has the advantage of permitting consistent reasoning over the broadest range of data scales. For instance, it is impossible to generate summary attributes about ordinal class attributes in spatial sets unless the sets are both subsets of the same universal spatial ideal.

3. Comparing Spatial Sets

In order to compare spatial sets, it is necessary to agree on the meaning of the term *equal*, which is often used in colloquial English for several different concepts about the relationship between two spatial datasets. For this purpose, three different forms of equal are defined called identical, equivalent, and similar.

3.1 Identity of Spatial Sets

Two sets *A* and *B* are *identical* if each and every member of *A* is a member of *B* and each and every member of *B* is a member of *A*. This is the traditional definition of set equality (Burington 1973). In addition, it is assumed that *A* and *B* are subsets of the same superset *S*. In effect, *A* is a true and faithful copy of *B*. It is possible for both *A* and *B* to be equal to *S*.

3.2 Equivalence of Spatial Sets

Equivalence is a mapping between two sets of objects such that there is a one-to-one relationship between all the members of set *A* and set *B*. There is no assumption of a common physical superset for two sets to be equivalent. While two identical sets are equivalent, the reverse is not necessarily true. Equivalence can also be achieved by transforming the elements of one set through a view function to be *view equivalent*. For instance, if set A is composed of cities with a location and population as class attributes and set *B* is composed of the same cities with location, population, and mean income for class attributes, a view *B'* could be generated over set *B* as a projection of the attributes location and population that is equivalent to set *A*. In this case set *B* is view equivalent to set *A* (Equation 1).

$$\begin{aligned} &Given: A\{location, pop\}, B\{location, pop, income\} \\ &A \cong B' \Leftarrow \pi_{location, pop}(B) \end{aligned}$$

3.3 Similarity of Spatial Sets

When two datasets are neither identical nor equivalent they are different. Depending on how much they differ, they may expose various degrees of similarity. In order for two datasets to be similar there must be some shared properties between the two datasets, but not necessarily shared elements. For instance, a set of water treatment plants in Maine and a set of post offices in Maine may have similar patterns and dispersions within the State, yet there are no post offices that are also water treatment plants.

Any measure of similarity is in its essence a distance measure, that is, a measure of the difference between a dataset and a target dataset (Tversky 1977). This distance concept is counterintuitive to the normal usage of similarity. If two datasets have a high similarity, their difference is small. When the difference between two datasets is zero, as assessed by some criteria, they are as highly similar as possible (100% the same). When the datasets are "highly" similar (difference zero) the datasets are equivalent with regard to the attributes measured, as long as they have elements of the same type.

4. The Content of Spatial Datasets

When one considers a spatial dataset and its contents there are two groups of attributes to examine: class attributes and set attributes.

4.1 Class Attributes

Class attributes are the attributes associated with the spatial objects in the dataset. The values recorded for each of the class attributes are distinguishing characteristics between the individual members of the dataset. These values and the manipulation of them through queries and functions have been the focus of traditional database technology (Elmasri and Navathe 1994; Ullman 1982). Query and analysis of class attributes can be computation-intensive and cognitively overwhelming in very large datasets.

4.2 Set Attributes

Set attributes are distinctly different from, but in some cases dependent upon, the class attribute values of the members of the dataset. The concept behind set attributes is that information about a dataset can be helpful in finding and sorting among several datasets.

Descriptive Attributes. Some set attributes, such as the data's source agency or region of coverage, are specific to the dataset itself and have nothing to do with the class attribute values of the objects in the dataset. These are *descriptive attributes* and are used primarily for cataloging the datasets. Attempts to describe such attributes through metadata are currently promoted by international and agencies (FGDC 1997; Weibel *et al.* 1997) and by spatial digital library research (Beard and Smith 1997). The burden of creating the metadata is the data producer's and is often considered uneconomical when datasets are perceived to have limited use to external users. This often results in cursory compliance with regulations regarding metadata generation.

Summary Attributes. Other set attributes, called *summary attributes*, are summary statistics for the contents of a dataset and can be traced to a direct relationship to one or more class attributes of the objects in the set. Examples are total population or mean income. Because there is a functional relationship between an element's class attribute value and the value of the set's summary attribute, it is possible to quantify the relative contribution of each element to a summary attribute value. This functional relationship in turn permits the selection of the most important elements, defined as largest contribution, in the dataset in terms of a particular attribute. The selection of the most important elements has direct application to operations that attempt to simplify large collections of data, such as cartographic generalization and data visualization. For example, New York City is the largest city in the United States, contributing about 3% of the total 1990 U.S. population. With as few as ten cities, it is possible to give an impression of the distribution of population in the United States as long as the most important (i.e., largest) cities are used. These ten cities may not sufficiently represent the spatial qualities of the dataset, but the dataset's population characteristics are preserved.

Synoptic Attributes. A third type of set attributes, called *synoptic attributes*, can be defined as functionally related to class attributes, but having meaning only with relation to the collection of objects in the dataset. Synoptic attributes, such as data ranges, data frequency, density, dispersion, and pattern, refer to qualities inherent to the spatial dataset. They are either invalid or nonsensical when the set is empty. While each element of the dataset contributes to the resulting characteristic, the element's contribution is its relationships with the other elements and is not quantifiable in the absence of the other elements. Synoptic attributes are of primary interest in evaluating spatial datasets and summary attributes can be used to evaluate the non-spatial aspects of the datasets.

5. Measures of Spatial Dataset Similarity

As stated previously, similarity is a distance function (Tversky 1977) between two sets that share a group of attributes. The scales of these attributes-measured according to Stevens's (1946) categorization into nominal, ordinal, interval, and ratio-determine the appropriate methods for evaluating that distance. In order for these various measures to be combined it is necessary to standardize all of the measures. We use the convention that a *similarity* value of one means that there is no measurable *difference* between the two spatial sets. A similarity value of zero means that the two spatial sets are completely dissimilar-as distant as possible. Once similarity measures are standardized it is possible for a user to set a desired similarity level in a meaningful way. For instance, similarity ($\approx$) could be defined for all datasets (*D*) over a given set of attributes (*A*) as having a difference (δ) of less than a 0.1 from the target (*T*) (Equation 2).

$$T \approx D \text{ if } \delta_{[A_1 \ldots A_n]}(T, D) \leq 0.1$$

Ultimately measures of similarity have the most value when two or more candidate datasets are being compared to a single target. The target could be a collection of attribute values from a known spatial set or may be a hypothetical spatial set whose values have been constructed in a query. In either case, the fundamental question is, “Which is closer in the evaluation space, the *target* and set *X* or the *target* and set *Y*?” (Equation 3a or 3b)

$$\delta_{[A,B]}(T,X) < \delta_{[A,B]}(T,Y)$$

$$(T,X) \gtreqless (T,Y)$$

5.1 Measuring Similarity on Interval and Ratio Scales

Making distance measures on interval and ratio scales is straight forward, since the ability to support difference operations is part of their definition. The standardization of these distances is more of a concern, however. In both interval and ratio scales the zero point for distances between values is set by the set attribute values of the target dataset (*T*). For most summary attributes and some synoptic attributes reasonable maximum distances can be defined by knowing what the actual ranges of values are for all the class attributes. When there is a fully defined universal spatial ideal A these values should be known and stored in the set’s metadata as summary attributes ($X_{\min}$) (Equation 4). When the datasets (*D*) being evaluated do not belong to a defined universal spatial ideal the ranges must be calculated by combining the known ranges of the separate datasets.

$$\Delta^{A}_{\text{attribute}} = 1 - \frac{|x_T - x_D|}{\text{Max}(x_{\max} - x_T, x_T - x_{\min})}$$

For example, local density of points in a dataset is often measured by calculating the mean of the distances of each point to its nearest neighbor. The maximum distance any two points can have from one another is the diagonal of the minimum bounding rectangle (MBR). If the MBR of the universal spatial ideal is not known then we can estimate the maximum mean nearest neighbor value by choosing the maximum MBR diagonal from the spatial datasets being evaluated. Because the calculation of maximum values for any particular set attribute is highly dependent on the semantics of the attribute it will be necessary to rely on the user or a domain specialist to define methods for the calculations of maxima.

5.2 Measuring Rank Similarity

There are several standard statistical measures used to compare two sets of ordinal values. However, measures such as Spearman’s rs and Kendall’s tau and gamma (Blalock 1972) are only useful for two separate variables and sets of equal size. Because there is an assumption that the two sets A and B share some elements one statistic is the number of shared objects (Equation 5), however, this measure loses the concept of rank similarity. For instance, two sets of cities that share Russell, Kansas and Hope, Arkansas would be assessed to be as similar as two sets that share New York and Los Angeles.

$$X = 1 - \frac{count(A \cap B)}{count(A)}$$

The rank similarity of a spatial set (*A1*) to its universal spatial ideal (*A*) can be evaluated if the objects in the universal spatial ideal are ordered on a common attribute. The ρ-score (Equation 6) measures the degree to which a subset’s members retain the rank importance of the original set. This assessment is done by comparing the sum of its *n* rank values to the sum of a hypothetical set containing the objects ranked 1 to *n*. The values for the ρ-score range between 0 and 1. A value of 0 indicates that the subset contains the n highest ranked members of the superset. If the *n* lowest ranked members of the superset are in the subset the ρ-score is 1. When *n* and the number (*N*) of elements in *A* are equal, the ρ-score is assumed to be 0 since the sets are identical by definition. A comparison of ρ-scores is only valid between two spatial sets if they belong to the same universal spatial ideal.

$$\kappa = 1 - \frac{\sum |f_o - f_e|}{\kappa_{\max}}$$

$$\kappa_{\max} = |N - f_{\min}| + \sum |0 - f_e| = 2(N - f_{\min})$$

The ρ-score is calculated in the following manner. Each subset member’s rank (R_i) in the universal spatial ideal (*A*) is summed for the entire range of the dataset’s (*A1*) *n* members. The expected sum, if the first *n* members of *A* were chosen, is subtracted from *A1*’s actual rank sum. This value is standardized with the expected sum of the ranks of the last *n* members of *A* (where *N* is the total number in *A*).

5.3 Similarity on Nominal Data Scales

Nominal data scales by definition cannot be ordered. It is, however, possible to evaluate the similarity of the nominal values in a given spatial ideal to those in its universal spatial ideal. For this goal, we must know the frequency of each particular value in the spatial ideal and the universal spatial ideal. The κ–score sums the differences between the frequencies of nominal values (f_0) in a set with the expected frequencies (f_e) (Equation 7). The result is normalized by the maximum difference that could occur by substituting the number of occurrences (N) for (f_0) in the category with the lowest expected frequency (f_e) and a zero is substituted for all other observed frequencies (Equation 8). The standardized form permits comparison between subsets of different sizes. The κ–score relies on a set of theoretical frequencies which were expected, this requires knowledge of the character of the universal spatial ideal and therefore can only be used where the ideal is known.

$$N = n: \quad \rho' = 1$$

$$N > n: \quad \rho' = 1 - \frac{\sum_{i=1}^{n} R_i - \frac{n(n+1)}{2}}{n(N - n)}$$

5.4 A Mixed-Scale Similarity Measure

Most sets of spatial data have a broad range of summary attributes and synoptic attributes, which need to be combined to accurately measure the similarity of any spatial dataset to a target set of attribute values. Since it is assumed that all similarity measures are standardized to values between 0 and 1, we can combine the values in a simple n-dimensional distance measure. Equation 9 combines a number (n) of measures of mixed data scales in a single similarity measure (σ), where A identifies the class definition of the spatial ideal. Each σ also includes an attribute list, which identifies the attributes over which the similarity has been calculated. A σ -score of 1 means that the datasets have the highest degree of similarity and, therefore, are equivalent, while a σ -score of 0 means that the datasets are completely different.

$$\sigma^{A}\left|\text{[illegible]}\right| = \sqrt{\frac{(\Delta^{A})^2 - (\rho^{A})^2 + \ldots + (\kappa^{A})^2}{n}}$$

A similarity index can be created over a collection of two or more spatial datasets by using the σ values to order the datasets (Equation 10).

$$S^{A}_{\text{[illegible]}} = \left\{\sigma^{A}\left|\text{[illegible]}\right|_1, \sigma^{A}\left[\text{[illegible]}\right]_2, \ldots, \sigma^{A}\left|\text{[illegible]}\right|_n\right\}$$

Because the σ values are created from summary and synoptic attributes, which can be stored as metadata, there is no need to access the data to evaluate similarity of the datasets. The open access to the metadata values makes it possible for individual domain experts to construct σ-functions, which express the particular semantics of their applications, rather than relying on predefined definitions of fitness for use explicitly stated in the metadata.

6. Conclusions

In this paper we distinguished the concepts of identity, equivalence, and similarity. In most digital spatial archives it is possible for each of these conditions to exist, but it is mostly likely that datasets will be similar, not equivalent, to one another. The ability to identify identical and equivalent datasets is relatively well defined and most database systems have utilities to identify redundant data items and datasets. Currently a difference of one item makes two datasets non-equivalent and results in both sets being stored. The elimination of redundant data items is a part of normalization in relational database theory (Ullman 1982), but we are focused on the dataset, with storage and retrieval of individual items. To better understand the degree to which two datasets are not equivalent it was necessary to define a model of datasets similarity.

A methodology for assessing similarity between a subset and a target dataset was specified to address the key question of how similar a subset is to its superset. This methodology has been defined in a general manner which handles dataset attributes in terms of their measurement scale rather than their semantics. Since the model of similarity can be applied in general to attributes on all scales of measurement and semantic content, it is necessary to examine and select a set of measures specific to spatial datasets. The values generated by these measures can in turn be used in the similarity model defined here to build a similarity index of the spatial similarity between a dataset and a target dataset. In most instances the target will be the universal spatial ideal. It is possible to define theoretical metadata for a desired dataset and to measure the similarity of all datasets to the theoretical target. This permits the user to query a digital spatial archive for datasets that are most similar to their needs.

When users request a sample of a dataset they can set a threshold level for similarity over a set of attributes. Using the model described here, it would be possible to determine when a subset meets that threshold. The sample can then be transferred to the users for analysis by whatever means they need to make a decision.

We will assume that the analysis of non-location class attributes and the generation of their summary and synoptic attributes can be handled by domain experts based on work that has been done in database technology (Mena et al. 1998; Bishr 1997) and data mining (Ng and Han 1994). The large body of research in spatial analysis and spatial statistics (Bailey and Gatrell 1995; Unwin 1981) suggests there may be measures of synoptic spatial attributes such as dispersion, density, and pattern that may be used to describe the spatial character of a dataset using the similarity methodology presented here.

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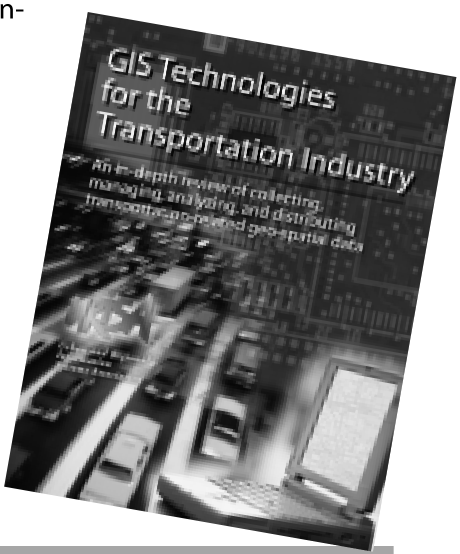

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Understanding Interorganizational GIS Activities: A Conceptual Framework

Zorica Nedovic-Budic, Ph.D.
Jeffrey K. Pinto, Ph.D.

Abstract: Widespread diffusion of geographic information systems (GIS) and related proliferation of spatial databases in digital form have prompted the practice of joint development and sharing of geographic databases. The ultimate benefit from the coordinated GIS developments and database sharing is reduced redundancy and duplication of effort and establishment of data partnerships and networks which are the building blocks of the National Spatial Data Infrastructure (NSDI). However, the multi-participant GIS activities are found to be much more challenging then the implementation of internal, single-agency systems and databases. To date, there has not been sufficient knowledge about the factors and processes that influence development and use of interorganizational GIS and databases. This paper provides a systematic literature review and builds a conceptual framework for better understanding and effective management of the interorganizational GIS activities.

Introduction

Previous research provides only partial evidence about the trends in interorganizational development and sharing of geographic information systems (GIS) and databases, the obstacles and facilitators of interorganizational activities, and the benefits derived from the joint activities. Anecdotal evidence is provided primarily through conference presentations, usually as a discussion of multi-participant or enterprise-wide developments and data sharing issues (Burton et al. 1998; Di Pollina et al. 1998; Ehler and Petrecca 1998; Hatton 1997; Reed 1998). Those sources provide a foundation for initial recognition of the relevant issues, but they stop short of systematic examination of factors and processes that permeate the efforts in digital spatial data development and sharing. The current GIS literature is scarce in evaluating the effectiveness and suitability of different sharing mechanisms in varying organizational and interorganizational contexts. Based on the literature in organizational studies, inter-group dynamics, exchange theory, political economy and research on GIS implementation and diffusion, we propose a comprehensive framework for understanding interorganizational GIS activities. First, we review the experiences in multi-participant GIS and database developments, and related mechanisms, policies, and outcomes.

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Sharing Practices

Redundancies in data developed and managed by individual agencies have long been recognized as issues of concern in both the private (Harralson et al. 1988) and public sector (Eichelberger 1986). Due to the widespread belief in the benefits associated with distributed databases, multi-participant GIS projects are being established along with single-user systems. Trends toward multi-participant or shared GIS projects have been evident in both the US and UK local governments (French and Wiggins 1990; Budic 1993; Masser and Campbell 1994; French and Skiles 1996; Warnecke et al. 1998). These sharing arrangements range from the manual exchange of digital data and "access only" policies, to fully shared distributed or centralized GIS and databases. Longitudinal data on UK authorities acquired by Masser and Campbell (1994) suggest a change in the rate of diffusion of the multi-participant GIS projects. Their data shows a decrease in the proportion of multi-departmental systems from over one half in 1991 to under one half in 1993, suggesting to them that sharing during that time period becoming increasingly problematic. During the same period there was a shift from corporate GIS projects involving all departments, to smaller scale ventures involving two to three participants.

With respect to coordination efforts, GIS developments in state agencies in the United States have evolved from the early, department-specific systems, through informal multi-departmental arrangements, to multi-agency, cross-departmental, and statewide foci (Croswell 1994). Several states have taken a proactive role in stimulating and coordinating GIS diffusion and modernization of land records at the local and regional government level where they can offer the financial and/or the technical support needed (Warnecke et al. 1992; Warnecke 1995). Increased practice of data sharing has prompted some states to initiate development of a common statewide base map. Texas Orthoimagery Program (Decker and Seekins 1997) is one example of such statewide effort.

At the federal level, efforts supporting the development and distribution of digital spatial data have been long-standing, beginning with the initiation of the National Mapping Division Digital Cartography Program in 1979 by the US Geological Survey. While the individual agencies have been using GIS technology for specific projects for more than two decades, until recently there were few pronounced mechanisms for coordinating spatial data resources at the federal level. Development of the GBF/DIME and TIGER files were significant advancements in data sharing. These projects that promoted data sharing among more than three hundred local planning agencies and successfully overcame bureaucratic inertia (Sperling 1995). Most recently, a significant step forward in advancing the comprehensive provision and exchange of reliable data among a variety of users, including all levels of government, private sector, and educational institutions is the initiative for development of the National Digital Geospatial Data Framework and Clearinghouse. (FGDC; Frank et al. 1996; Coleman and Nebert 1998; Smith and Rhind 1998)

Sharing Obstacles and Facilitators

Both technological and organizational difficulties are more likely to be encountered in building interorganizational GIS and databases. Campbell and Masser (1995) point out the following specific problem areas: a) variations in priorities between participants; b) differences in the ability to exploit GIS facilities; c) differences in the level of awareness and spatial data handling skills; and d) agreements over access to information, leadership, data standards, equipment, and training (p. 236). Azad (1998) proposes the functional diversity among various participants as the major challenge in developing enterprise-wide systems.

On the technical side, there have been problems in coordinating system requirements (Croswell 1991; Calkins and Weatherbe 1995b); lacking common data definitions, formats, and models (Frank 1992; Dawes 1996); differences in data quality (Frank 1992); and networking costs. While those problems tend to cause less than desirable system performance, they have been gradually alleviated through technical solutions toward interoperability and open systems (Bishr 1998; Laurini 1998; Voisard and Schweppe 1998), distributed data processing in heterogeneous environments (Abel et al. 1998), integration of federated databases (Devogele et al. 1998), and the use of World Wide Web for data distribution and viewing (Heikkila 1998).

Data confidentiality, liability, and pricing are further constraints to interorganizational GIS efforts. Data access policies established by individual organizations are ultimately going to affect data exchange activities and benefits accruing to various data users and producers (Lopez 1996; Onsrud et al. 1996). In her survey of inter-agency information sharing, Dawes (1996) finds inadequate planning and consultation about data use, and insufficient staff and technical resources as frequent obstacles. Other external obstacles include institutional disincentives, historical and ideological barriers, power disparities, differing risk perceptions, technical complexity, and political and institutional culture (Citera et al. 1995). With a similar set of factors operating in the state government agencies, Sperling (1995) adds staff turnover, lack of resources, archaic systems, and lack of support and commitment from managers and officials, as preventing effective development and sharing of geographic databases.

Organizational settings and interorganizational relations significantly complicate the implementation of multi-participant GIS projects and can jeopardize the benefits of the joint database development and sharing. Organizational reluctance to share GIS files due to a fear of losing autonomy, control over information sources, independence, and organizational power is widely acknowledged (Bozman 1989; Pinto and Azad 1994; Azad and Wiggins 1995; Meredith 1995). Interorganizational systems increase interdependencies (Azad and Wiggins 1995), create the potential for power shifts (Stern and Craig 1971), and frequently invoke “turf” (Dawes 1996). Those relationships are dominated by interorganizational politics (Azad 1998).

A recent study on data resource management (DRM) in distributed computing environments identifies four conditions that need to come to a congruent “gestalt fit” in order to secure system success. This fit is present in “organizations represented by a well-blended configuration of high intersite data dependence, high centralization of IS decisions, high concentration IS resources at the central site, and low DRM-related autonomy granted to local sites” (Jain et al. 1998, p. 1). Azad (1998) suggest the utmost importance of management, while Evans (1995) notes that teamwork and joint interest in applications, flexibility of the system development, and willingness to incorporate institutional learning are necessary conditions for GIS data sharing to be successful.

These are all difficult prerequisites when compared to the advantages of a single user approach that presumes more independence, autonomy, and control (Campbell and Masser 1995). To make the interorganizational strategies easier to implement, it is of great importance to identify organizational factors that influence the efforts to coordinate GIS activities across organizational boundaries. Such attempts have already been made in several fields (policy implementation, organizational studies, management), including the contributions made so far through the National Center for Geographic Information and Analysis (NCGIA) Initiative 9 on Institutions Sharing Geographic Information (NCGIA).

Benefits from Sharing

The existing evidence concerning the benefits from multi-participant GIS and databases is generally positive, but in some cases ambiguous, due to a greater complexity of implementation and difficulty in achieving the operational impacts (Campbell 1991; Azad and Wiggins 1995). Sharing the cost of implementation among several participants, and boosting of productivity and decision-making through exchange of information are two main potential benefits from multi-participant approaches (Brown and Brudney 1993). In the past databases shared by many users were found to be cost effective (Levinsohn 1989), promulgate savings, improve data quality (Harralson et al. 1988), and yield the highest returns on investment (Tveitdal and Hesjedal 1989). French and Skiles (1996) find that distributed and centralized multi-participant systems are perceived as more effective and their users are more satisfied than the users of single-agency systems. Respondents to Dawes' (1996) survey recognized benefits in better and more integrated planning and policy development, problem solving and relationship building, with positive impact increasing with more experienced users. In her survey of southeastern planning agencies, Budic (1994) suggests that GIS sharing contributed to reduced time spent in data collection and decision making, inclusion of more diverse maps, and increased availability of data.

Some system benefits stem from the process of coordination itself. Coordination can offer a number of intangible advantages, such as improved morale, learning, self-confidence, and confidence in others. Coordination can also generate some frustration, lower confidence in the other participants, and create extra work (Tjosvold 1988). There are a few other impacts that are related to organizational interdependencies. For instance, Brown et al. (1998) report that productivity, performance, and decision-making are all negatively related to greater resource interdependence. Dawes (1996) found a limiting effect on the professional discretion in policy design and program decisions. Given the contradictory evidence from the fields of interorganizational relationships, organizational studies and information systems research, the impact of coordination in development and use of GIS databases is hard to predict.

Conceptual Framework

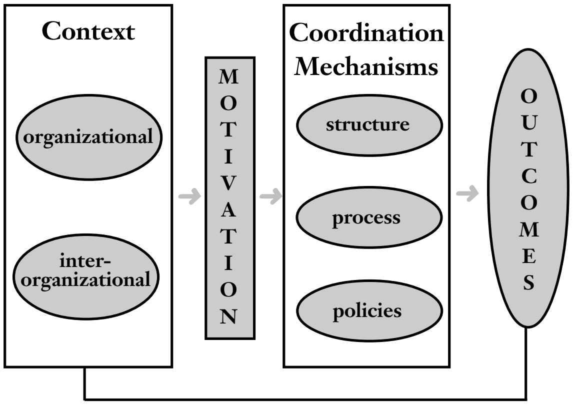
It is of ultimate importance to provide empirical evidence of the organizational and behavioral factors related to sharing of spatial databases and other joint geographic information system activities. The literature on organizational interdependencies, organizational internal and environmental factors, interorganizational relations, and policy implementation provide a number of useful concepts and paradigms to guide studying and managing joint development and sharing of geographic data. Drawing on his extensive professional experience, Kevany (1995) provides a comprehensive list of the factors relevant to GIS data sharing. Those factors include sharing classes; organizational environment; need for shared data; opportunity to share data; willingness to share data; incentive to share data; impediments to sharing; technical capability for sharing; and resources for sharing. A conceptual framework presented here builds from Kevany's ideas, but draws on a broader literature base to derive four general theoretical constructs on coordinated GIS developments and database sharing. Those constructs include context, motivation, coordination mechanisms (structure, process, and policies), and outcomes (Figure 1).

Interorganizational Context

Interorganizational context refers to the organizational factors and interdependencies that influence coordination and decisions about joint GIS and database activities. Despite the limited ability to manipulate the contextual factors, and in particular when considering the prospective scale of the NSDI, the context is very important in understanding the geographic information relationships and activities. Those relationships and activities can only be examined with respect to their context. Interorganizational systems and databases are manifestations of the interorganizational relationships (Kumar and Dissel 1996) and models of government (Westin 1991). Relating the context and GIS activities should help assess the applicability and functionality of sharing structures and policies in various interorganizational settings and under different organizational circumstances. Azad (1998) maintains that "working the context" is necessary for raising the odds of an enterprise-wide GIS implementation success.

The building blocks for studying GIS sharing as reviewed by Azad and Wiggins (1995) include: organizational exchange theory (Cook 1977); interorganizational relationship determinants (including necessity; asymmetry; reciprocity; efficiency; stability and legitimacy Oliver 1990); organizational interdependence (Thompson 1967); and or-

Figure 1



ganizational relations intensity (with coordination implying the highest intensity, preceded by collaboration and cooperation) (McCann 1983). Levine and White (1969) define exchange as "any voluntary activity between two organizations which has consequences, actual or anticipated, for the realization of their respective goals or objectives" (p. 120). Exchange is usually sought with the minimum loss of organizational autonomy and power, and depends on the availability of alternative resources.

Thompson (1967) identifies three types of organizational interdependencies, from lesser to increasing complexity: pooled; sequential, and reciprocal interdependency. Meredith (1995) postulates that already existing organizational interdependence will reduce the resistance to interorganizational sharing. This is particularly true for cooperative interdependence (Tjosvold 1988). However, increased interdependence and need for cooperation can in some situations lead to conflicts over authority, jurisdiction, and distribution of power. On those lines, Kumar and Dissel (1996) relate the type of interdependency and interorganizational system and potential for conflict (Table 1). An adversarial view of other actors "coupled with a short-term, gain-taking mentality can result in opportunistic behavior by one or more participants" (Kumar and Dissel 1996, p. 280).

A number of researchers have examined the types of factors that can influence the quality of interorganizational relations. Meredith (1995) identifies ambiguity and complexity as important determinants of the level of resistance to interorganizational ventures. Craig (1995) finds that institutional inertia can contribute to resistance to cooperation. Many other environmental factors can affect interorganizational exchange, including: organizational structure, resources, stability, culture, quality of relationships, bureaucratization of rules and procedures, incentives, and leadership (Cummings 1980; Van de Ven and Ferry 1980; Tjosvold 1988; Calkins et al. 1991; Obermeyer 1995; Pinto and Onsrud 1995; Brown et al. 1998). Finally, interdependence and greater mutual resources also tend to increase the number of joint decision points, and thus constrain the decisions and the probability of successful joint implementation (Aiken and Hage 1968; Pressman and Wildavsky 1984).

Motivation for Interorganizational GIS

Underlying the discussion of the value of coordinating interorganizational GIS and database activities is the need to identify the motivations that would impel organizational units to get actively involved in relationships with other organizations. A number of factors contribute to the perceived need to seek out interorganizational geographic information relationships. Coordination can be based on:

- authority, i.e., deriving from a sense of duty;
- common interest of organizations that value the same goals); or
- exchange inducements when returns are expected or received (O'Toole and Montjoy 1984).

Participation can be voluntary or mandated (Cummings 1980). The amount and contents of interorganizational interaction are often determined by the primary function of an organization (Levine and White 1969). In the GIS literature, the following reasons are cited as motivating the GIS related interaction: organizational needs, capabilities, and cost (Calkins and Weatherbe 1995); power relationships; appeals to professionalism and common goals (Obermeyer 1995); incentives, superordinate goals, accessibility, and resource scarcity (Pinto and Onsrud 1995).

Cost saving has been the major reason for interorganizational engagements. Governmental agencies often form partnerships as a vehicle to streamline their costs under the circumstances of fiscal pressures (Brown et al. 1998). In the case of GIS, the main saving is achieved through reduced duplication of efforts in developing digital databases (Larsen 1976). While the economic arguments are most common in the literature on interorganizational systems, Kumar and Dissel (1996) alert to the importance of technical and socio-political arguments in explaining collaborative alliances. Creating synergisms for better insights is an example of such non-economic argument (Craig 1995).

The bottom line of successful interorganizational endeavors, however, is the participants' willingness to form partnerships, to share both the benefits and the risks, and to reach agreement on many practical issues. The success depends on the internal motivational factors, i.e., on the spirit of cooperation and commitment to sharing (NGDPF 1993; Meredith 1995).

Coordination Mechanisms: Structure, Process and Policies

The central element in the conceptual framework presented here is the geographic information relationship. The relationship assumes interorganizational structures and policies employed, and the history and process undergone in coordinating multi-participant GIS and in establishing sharing relationships. Isolating and learning about the most robust coordination mechanisms and the most functional policies used would be of extreme utility in understanding and effectively managing geographic information relationships. Establishing formal standards, agreements, and coordination structures are necessary preconditions to any distributed GIS (Meredith 1995). Formalization tends to facilitate institutionalization of joint behavior, binding, and commitment (Brown et al. 1998).

Structure

Any joint GIS-related activity involves redefinition of existing tasks and structures and creation of new ones (Azad and Wiggins 1995; Azad 1998). Structure of an interorganizational relationships is established by specifying roles, obligations, rights, procedures, locations, information flow, data, analysis and computational methods used in the relationship (Kumar and Dissel 1996). Structure reduces the ambiguities by formalizing the form, process and content of the relationship, and by implying a level of agreement about mutual expectations.

Godschalk, et al. (1985) describe three models with regard to distribution of computing equipment and responsibilities: 1) distributed processing, 2) centralized processing, and 3) decentralized processing. Clearly, only the first two models involve sharing and coordination of system's development and use, although, theoretically, the third model does not exclude interaction. Jain et al. (1998) suggest centralized configurations are likely to result in more successful data resource management.

Azad and Wiggins (1995) propose another typology of multi-participant GIS settings. Their classification reflects the dynamic relationship between the involved organizations, direction and reciprocity of data exchange: a) "one way" relationships in which one agency is the provider of data at nominal cost to one or more consumer agencies; b) "somewhat one-way" relationships in which there is a limited exchange/return of products from the user agencies; and c) "two way" relationships which entails joint building and maintenance of geographic databases. Calkins and Weatherbe (1995a) identify four modes of spatial data sharing, including user-driven random transfer, owner-driven random transfer, cycle-driven transfer, and cycle-driven exchange.

Dueker and Vrana (1995) identify three forms of database integration, including core database integration, database constellation, and marketplace integration. Core database integration happens by coordination at the interorganizational level, while the other two are incidentally compatible. Although the NSDI initiative is primarily concerned with access to data and integration of local data to seamless national datasets, it requires networking capability and organizational structures to facilitate the electronic data transfer. Database is, therefore, only one of several possible components of integrated information systems. In addition to data, information about data (metadata, data dictionaries), system functionality (software, hardware), personnel (Nyerges 1989), applications, and space are candidates for sharing.

In summary, there are numerous ways to structure interorganizational GIS and database activities. These various configurations in developing and exchanging GIS resources often depend on the given institutional, technical, and economic constraints (Dueker 1987). According to Meredith (1995), less complex and unambiguous structures will diminish the resistance to interorganizational sharing, although Brown et al. (1998) find that simple structures do not unambiguously lead to better outcomes. They suggest, however, that "more complicated relationship structures will likely impact negatively on implementation capacity".

Process

GIS implementation in organizational settings is in itself a complex process that involves installing, maintaining, and using a system in environments that have diverse functions, tasks, resources, motifs, interests, and goals. Obviously, for GIS and databases to be jointly built or shared, there needs to be a critical mass of participants interested in the geographic information relationship (Azad and Wiggins 1995). The participants take various roles, such as information providers, service providers, distributors, and users (de Brisis 1995).

Interorganizational GIS activities raise the opportunities for complications in establishing partnerships, and require negotiations over cost, accuracy, responsibility, and many other issues involved (PTI/ICMA, 1991). Reaching the agreements on those many issues is the greatest challenge. Azad (1998) refers to coordination as the key vehicle for coping with setbacks and problems, guiding relationships, and managing production and use of the common datasets. The NSDI initiative recognizes the process of coordination among various public and private organizations as an inherent part of developing the information network.

Interorganizational relationships develop through three sequential phases: problem setting, direction setting, and structuring – each phase corresponding to gradually more intensive forms of interaction – collaboration, cooperation, and coordination (McCann 1983; Azad and Wiggins 1995). Coordination, obviously implying the closest interaction, is necessary in joint GIS activities. The type and level of the coordination process applied depends on the nature of the interorganizational relations (Cummings 1980) and the type of interdependencies existing between organizations (March and Simon 1958). Kumar and Dissel (1996) suggest that pooled interdependence requires coordination by standardization; for sequential interdependence it is appropriate to apply coordination by plan; and with reciprocal interdependence coordination is pursued by mutual adjustment (Table 1). Examining the development of the interorganizational relationships and the process of coordination over time is important for understanding the current rationales and circumstances of joint GIS and database activities.

Policies

Policies are necessary for establishing and maintaining interorganizational GIS activities, and, therefore, have to be clearly defined. A summary of the issues for which policies will need to be developed, agreed upon, and implemented if some level joint GIS and database activity is to be exercised is provided below. The issues are grouped into five broad categories: data, responsibility, ownership, contribution, and incentives.

1) Data: The need for standards increases with intensified practice of GIS and data sharing activities. The standards are necessary for determining the fitness of data for different users (Rushton and Frank 1995). If well developed and adhered to by various parties, standards can reduce the cost of sharing (Bossler 1995). Interorganizational systems require standards on data models; data formats; data quality; categories of spatial data; contents of specific data layers; metadata; data dictionaries; output requirements; and data transfer. The standardization can extend to the whole database design (Calkins and Weatherbe 1995b). Various GIS-related standards are adopted or developed at international and national levels (Salge 1998), as well as among regional and local clusters of GIS data users and producers (Nedovic-Budic and Pinto 1998). The more generic standards are, i.e. the more independent they are from existing data models and software formats, the more useful they are in facilitating data sharing. For example, Arctur et al. (1998) criticize the Spatial Data Transfer Standard (SDTS) for limited applicability across multiple data models, and suggest ramifications for this unintended shortcoming.

2) Responsibility: Further policies need to be established to guide responsibilities for database development; deposition of data; database maintenance; data usage; distribution of data; user support; and decision-making. The importance of agreements on not only data delivery but on maintenance aspects can not be overemphasized (Frank 1992; Nedovic-Budic and Pinto 1998). Azad (1998) confirms that "even if an enterprise GIS is launched in a multi-participant setting and a useful spatial database gets built (internally or outsourced), the issue of keeping the data up to date and current becomes an independent challenge which can overwhelm the institutional apparatus with the best technical staff and the most progressive managers ".(p. 1-4)

3) Ownership: Besides the responsibilities, it is important to clarify data ownership. The ownership-related policies need to be very specific and unambiguous. Vaguely defined policies could lead to many problems related to unresolved ownership issues. Equally important to the actual ownership is a sense of ownership, which can best be instilled through user involvement (Leonard-Barton and Kraus 1985; Hunton and Beeler 1997). Security features, such as additional routers, firewalls, and passwords are often necessary to support the agreements on responsibility and ownership (Lopez 1998).

4) Contributions: Funding of database development and maintenance; pricing for data distribution; charges for user support; hardware, software, and staffing expenses all need to be resolved and coded as an interorganizational policy. Equitable and fair cost allocation is crucial for a multi-participant system to be sustainable (King 1995; Nedovic-Budic and Pinto 1998). The method used in allocating the costs, however, is challenging to determine. In addition to the monetary contributions, bartering (Bossler 1995) and in-kind contribution of available assets and skills (King 1995) are also useful and effective means of exchange.

5) Incentives: Given that spontaneous coordination in interorganizational policy and projects are rare (O'Toole and Montjoy 1984), incentives are crucial instruments for stimulating interorganizational GIS activities. Chau and Tam (1997) find that the organizations tend to be more "reactive" than "proactive" in adopting open systems technologies. Therefore, the agencies need to be "pulled" or "pushed" into the sharing relationship (Azad and Wiggins 1995). Incentives do not necessarily need to be monetary (Bossler 1995). Minimizing cost and generating valuable social outcomes are two general incentives assumed by many organizations exchanging data (Taupier 1995). Craig (1995) suggests that expanded organizational mandates can secure change and counter institutional inertia. May and Burby (1996), however, alert that cooperative policies are more effective than coercive mandates in sustaining long-run implementation commitment in local governments. In addition to possible external incentives (or mandates), coordinating agencies can also use a set of internal incentives to realize joint GIS and database sharing goals.

Policies between organizations involved in joint GIS and database activities can be: a) formalized, documented, and guided by prescribed procedures and designated cross-organizational entities; or b) implemented as unwritten rules and verbal understanding of mutual conduct and obligations with no coordinating cross-organizational entity. The most common documents that are used to formalize interorganizational GIS activities are memoranda of understanding and intergovernmental agreements. The joint activities are usually coordinated by establishment of overarching bodies in form of multi-agency bureaucracy or

Table 1. *Interorganizational Interdependence, Coordination Mechanisms, Structurability, and Potential for Conflict (Adopted from Kumar and Dissel 1996)*

CONFIGURATION OF INTERDEPENDENCE	POOLED	SEQUENTIAL	RECIPRICAL
COORDINATION MECHANISMS	STANDARDS & RULES	STANDARDS, RULES, SCHEDULES & PLANS	STANDARDS, RULES, SCHEDULES, PLANS & MUTUAL ADJUSTMENT
STRUCTURABIITY	HIGH	MEDIUM	LOW
POTENTIAL FOR CONFLICT	LOW	MEDIUM	HIGH

management structure. Those overarching bodies have an important role in coordinating implementation activities; promulgating standards; developing data and cost sharing agreements; ensuring participation and compliance with interorganizational activities; preventing individual organizational approaches to collide; and escaping the "bureaucratic void" (Stage 1995; Ventura 1995).

Outcomes

The outcomes are the effects of the interorganizational GIS and database activities on the substantive application areas, as a measure of the value and social utility of geographic information (Onsrud and Rushton 1995). GIS sharing benefits cannot be separated from the value of final decisions and social outcomes to which they contribute (Taupier 1995). In theory, the interorganizational geographic information relationships appear to offer notable benefits in:

- efficiency (i.e., cost savings and productivity benefits from existing operations being performed at lower per-unit cost);
- effectiveness (enhanced capabilities for unit; new and better quality products; improved policy and decision-making);
- enterprise benefits (new responsibilities; broader mission); and
- public service (Brown and Brudney 1993; Dueker and Vrana 1995; Dawes 1996; Nedovic-Budic 1998).

Several criteria commonly employed for measuring the impact of information systems in organizations are (DeLone and McLean 1992): system quality, information quality, information and system usage, user satisfaction, individual impact (i.e., contribution to decision-making), and organizational performance (i.e., efficiency and effectiveness). While all six criteria can be applied in the evaluation of GIS benefits in interorganizational settings, the main difficulty remains in separating the effects of database sharing from the other general impacts of automating geographic data resources. Efficiency, effectiveness, and decision-making impacts are discussed below in more detail.

When one organization is able to make direct contact with another party who possesses needed information, there is far less likelihood of replication of effort in creating and maintaining databases (Grimshaw 1988). Savings may also accrue during hardware and software acquisition and assignment of the personnel in charge of a GIS (Campbell 1990; Campbell 1991). An organization's efficiency is enhanced through this sharing process. Gillespie (1991) suggests that one measure of enhanced efficiency would be to compare the difference in variable costs (labor, time, and money) of producing all necessary information in-house versus retrieving that information from other sources who have, in all likelihood, already produced the needed information. It is readily apparent that in avoiding the duplication of effort from information reproduction, organizational sharing aids in improved efficiency.

Effectiveness has been defined as the case when GIS programs "increase the quality of the output or produces a new output" (Gillespie, 1991: p. A-85). Gillespie suggests a decision rule for determining the increased effectiveness to be derived from information sharing. The rule has three requirements: first, considering how GIS output and accessibility are different given our ability to share and borrow data from other sources; second, questioning if this new data matters, that is, does having access to such data also mean that members of our organization are using it; and finally, is this data useful to our work? Is the overall effect of its use "valuable" to our department? If the answer to any of the above questions is "no," Gillespie argues that our data has failed the test of enhanced effectiveness.

With regard to decision making, Zwart (1991) argues that unless we can determine that utilization of geographic information has led to enhanced or better decision making capabilities, its impact is minimal. As a result, if information that is shared between organizations does not lead one party to actively reassess decision priorities or value structures, the third criterion of outcome (decision making) is not fully addressed.

Finally, numerous other impacts, and unexpected benefits are also possible (Gillespie 1991, 1992; Taupier 1995). Interorganizational cooperation can, for instance, strengthen work relationships and morale and thus contribute to productivity, task completion (Johnson et al. 1981; Johnson et al. 1983), and satisfaction of information users (Ives et al. 1983). Public service (Brown and Brudney 1993) and equity (Epstein 1995) are data sharing benefit that extend beyond organizational boundaries, and are related to broader societal outcomes.

Conclusion

The challenge of improving the efficiency and effectiveness of geographic information sharing rests firstly on our better understanding of the motivations and processes that are likely to influence such exchanges, either positively or negatively. Research to date offers glimpses of the problems associated with such data sharing, as well as some opportunities for those organizations that are able to override issues of organizational inertia, mistrust, and "turf." One common point raised by much of the work done to date suggests that resistance to data sharing is typically not related to technical issues; that is, incompatible systems or data structures. Rather, we continue to find that these challenges are first and foremost "people" challenges; they represent the need to better isolate and address the human factors that are likely to impede free data sharing across organizational boundaries. As a result, this paper offers a number of research opportunities and testable propositions for those interested in better understanding and ultimately, facilitating the exchange of geographic information.

The paper presents a comprehensive literature review and a conceptual framework for understanding various aspects in the process of developing and sharing digital data generated with geographic information system (GIS) technology. The framework includes organizational and interorganizational context, motivation, coordination mechanisms, and outcomes of sharing GIS and databases. The framework relates several important concepts into a coherent model:

- The most important concepts relevant for understanding the multi-participant GIS context have to do with intensity and quality of interorganizational relationships, organizational interdependence, resources, structure, stability, culture, politics, and leadership.
- Motivation for interorganizational GIS activities ranges from economic and socio-political to technical arguments. Joint efforts result from the sense of duty, common interest, or exchange inducements, and are pursued as voluntary or mandated.
- Coordination mechanisms are manifested through established interorganizational structures, processes, and policies. Structure is defined through organizational forms; channels, direction, and methods of information flow; and level of shared components (i.e., database, hardware, software, personnel, space, and applications). Coordination process can be undertaken through standardization, joint planning, or mutual adjustment. Formal or informal policies are established to address data-related issues, responsibilities, ownership, contributions, and incentives.
- Finally, the outcomes of interorganizational GIS activities can be assessed using a number of criteria, including efficiency, effectiveness, decision-making impact, societal equity, and public service. The effect on developing and strengthening regional and local networks and partnerships, however, is one of the most valued expected benefits from building the National Spatial Data Infrastructure (NSDI).

Our understanding of GIS and database sharing needs to draw on all those concepts as they determine and affect the decisions, processes, and effects of interorganizational activities. Changing technological environment, such as the development of open systems, advances in networking and distributed data processing, and the use of World Wide Web for data distribution and access, make it difficult to study the continuously evolving multi-participant GIS implementation settings. However, many of the non-technical factors addressed in this review paper, are more stable, and will continue to pervade the efforts to integrate and share geographic information systems and digital spatial databases across organizational boundaries. Better insight into those factors will help eliminate redundancies in database developments, and will lead to more effective interorganizational GIS implementation strategies.

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