December 1998

Geographic Information Systems in Developing Countries: Issues in Data Collection, Management, and Use

Lawrence West
University of Central Florida

Brian Mennecke
East Carolina University

Geographic Information Systems in Developing Countries: Issues in Data Collection, Management, and Use[1]

Lawrence A. West, Jr.
Department of Management
University of Central Florida

Brian E. Mennecke
Department of Decision Sciences
East Carolina University

Introduction

Although the trend in many developed nations is to decentralize government planning and management, centralized planning is continuing to increase in importance in developing nations (Todaro, 1994; Gillis, et al., 1992). In particular, many third world governments plan a larger relative share of their economies than do governments in developed countries (Todaro, 1994; Gillis, et al., 1992). Unfortunately, centralized government development activities are hampered by two factors identified by Todaro, the lack of adequate data and of trained decision makers (1994, Ch. 16). In particular, spatial and attribute data describing the geographic distribution of economic resources, populations, and other factors affecting development present significant problems for government planners and leaders.

Geographic information systems (GIS) are a type of data management and decision support system that have been shown to be useful in supporting decision makers in public planning and administration (Brudney & Brown, 1992; Drummond, 1995; Grupe, 1992; Worrall, 1994). GIS enable the collection of conventional (attribute) data and geographic (i.e., spatial) data. Because many planning decisions include geographic concepts, these systems can be useful in helping to organize public and private resources and make policy decisions. Although GIS have the potential to assist governments in managing development, the spatial data that drives these systems present a host of collection and management problems. This paper discusses several of the problems related to using GIS in the third world and offers potential solutions for addressing these problems.

Issues Impacting GIS Use

Unfortunately, GIS capabilities are largely unavailable in the majority of the nations around the world. For example, a recent UN survey found that only 44 of the 210 countries surveyed reported that they used GIS (United Nations Statistical Division, 1997). In most cases this is because there is a shortage of spatial and socioeconomic data. For example, Gerland (1996) notes that "The problem remains that very little of this information is spatially referenced and organized, making it difficult or even impossible for analytical studies, monitoring, planning, and decision-support to take place" (p. 9). This is because spatial data and GIS present a unique set of management and collection problems (Onsrud & Pinto, 1991). Because many researchers are likely unaware of these problems, it is worthwhile to review and discuss these issues.

Acquiring Accurate Source Data

A typical approach used for generating GIS data is to digitize existing paper maps. Unfortunately, these maps often contain inaccuracies and inconsistencies. For example, a study of GIS use in the Philippines conducted by the U.S. Bureau of the Census (Leddy & Fuller, 1996) showed that the primary base maps used to generate digital maps were created in the 1940's and 1950's. Unfortunately, in developing countries data sources such as these are often all that are available for building GIS data sets.

Data Integration

Many developing countries do not collect even basic statistical data about their population or the economy. Further, there are few standardized data collection efforts (Gerland, 1996). Integration problems include missing positional information, inconsistent classifications and methodologies, different spatial units, different levels of aggregation or resolution, spatial data gaps, and different time references for the data.

Resource Constraints

It is often difficult for fiscally constrained governments to justify the initial investment when other, more pressing projects exist (Innes & Simpson, 1993). Further, implementation efforts that last for many years often have the potential to extend past

[1]The review of the paper was managed by George Marakus.

the tenure of those who initiated the project (Leddy & Fuller, 1996). A second resource issue is that of trained personnel. Leddy and Fuller (1996) observed that when Filipino government employees acquire training and competence in GIS, they are likely to move to more lucrative positions.

Organizational Politics

Organizational political behaviors (OPB) have been observed to have a significant impact on the implementation of GIS in organizations in the U.S. (Pinto & Azad, 1996). An important issue is conflict over GIS and other IT resources. For example, many governments are not willing to collaborate in the development and administration of GIS and spatial data. This is a particular problem when significant resources have been expended to develop and collect spatial data and technologies by local governments. This type of problem is likely to arise not only because of interpersonal and institutional constraints, but also because these organizations likely do not have significant formal protocols and policies for collaboration.

Promoting GIS Use in the Third World

Despite the impediments to GIS system development discussed above there are strategies and techniques available to countries that wish to take advantage of GIS.

Automated Data Acquisition

Global positioning systems (GPS) and remotely sensed imagery (RSI) offer the potential to provide vast quantities of useful data for third-world nations. By equipping agency employees with GPS devices the location of features can be recorded as a routine part of employee duties. For example, Dugger (1997) showed how GPS could be used to create maps showing the locations of solid waste disposal sites in Thailand. Hightower et al. (1997) used GPS technology to collect land use data and data on mosquito breeding habitats in the Lake Victoria region of Africa. In both of these cases GPS was used by personnel to collect data while undertaking field operations that were a normal part of their activities.

Another source of data for map creation is remotely sensed data (Bhatt, 1992; Karnik, 1993). An advantage of RSI is that maps created using this technology are usually significantly less expensive than those created using ground-based approaches. For example, Pratt et al. (1997) showed that a mapping project using RSI significantly reduces data collection costs. An additional advantage of RSI is that data for most of the world are available (Goodrich et al., 1996). For example, NASA has begun a program called the NASA Commercial Technology Network to promote the use of NASA technology for commercial applications. In one project, data from NASA satellites were used by a coffee company in the U.S. to produce vegetation and crop health maps (NASA, 1994). The maps allowed managers in the firm to improve their understanding of the coffee market and also help farmers and government administrators in Central and South America to better manage their own resources. RSI from commercial organizations have also been used to aid development efforts. For example, Haack et al. (1996) used SPOT satellite imagery to capture data about the extent of urban expansion in Kathmandu, Nepal. Similarly, Corbley (1997) used RSI to create maps for urban planning and natural resource management in India. Some third world countries have even begun to develop their own RSI capabilities. Brazil, for example, plans to invest more than $1 billion in satellite technology by the turn of the century (Goodrich et al., 1996).

RSI is particularly useful when used to identify physical features such as roads, villages, natural resources, and similar objects (Wang et al., 1992). In addition, imagery is also useful for comparing data over time. In Tijuana, Mexico aerial photographs and maps from two time periods were merged and compared to update and quantify urban growth (Bocco & Sanchez, 1995).

Standardized Infrastructure Requirements and Policies

Of primary importance in developing a robust GIS environment for use in the third world is the need to develop an infrastructure that is capable of supporting users of spatial technologies. First and foremost is the need to establish a set of national-level standards for applications and data formats (National Research Council, 1994). Standards should address issues such as map projections, data resolution, and the spatial database schema. A strategy for developing standards should include the development of a standardized metadata repository (i.e., a data dictionary). Beyond this, however, it must also be recognized that the accuracy of any GIS data is dependent on the underlying reference scheme and map scale. If different organizations use different maps with different levels of accuracy then the ability to integrate this data will be impaired. This problem can be addressed by funding at the national level maps containing political boundaries and other features. Of course a national-level data collection program can create its own set of problems. Experiences from developed nations suggest that large-scale efforts to develop national spatial data resources can have unanticipated and problematic consequences. These include problems such as collection efforts that produce data that are inappropriate for local users' needs; data collection efforts that are slow and produce obsolete output; and problems with identifying costs and assigning costs to specific products or users (National Research Council, 1994; p. 12). One solution to this problem is to develop national standards but to encourage local collection and management of the data.

Leveraging Resources and Strategic Partnerships

Because of the complexity of the problems in many nations, there is no one solution that will address all of these constraints. Nevertheless, there are several policy initiatives that will improve the likelihood that GIS will be successfully utilized. For example, many developing nations have natural resources, a strategically important geographic location, a large labor pool, or a potential market for selling products that organizations from developing nations will seek to exploit. When a third world government lets contracts for transportation, telecommunications, construction, etc., contracts should include provisions that contractors provide compatible datasets pertaining to the objects of interest (e.g., microwave towers, wells, etc.). Similarly, when projects involve natural resource development, the permitting process should require that reports be submitted using GIS techniques and that the organization include other data as part of development activities. This practice is common in developed nations. For example, the City of Raleigh in North Carolina requires that all building permits be authorized only when contractors include blueprints and maps in a format compatible with the City's systems. Third world nations can also form mutually beneficial partnerships with aid agencies, the U.N., universities, and other organizations. For example, Pohl (1995, 1996) completed a digital mapping project for Indonesia that was funded by a European research agency and a university. When completed, Indonesia took possession of high quality base maps for a large part of the country.

Managing Organizational Political Behaviors

To maximize the potential for successful GIS implementation in the face of political behavior, managers must operate as *sensible* organizational actors by learning to use OPB as a tool (Pinto & Azad, 1996; Pinto, 1997). Pinto (1997) suggests that managers should develop "appropriate" political tactics, which means being sensitive to the concerns of powerful stakeholder groups and developing strategies for influencing and negotiating with them. To accomplish this, managers should consider the concept of "WIIFM" (What's in it for me?) in order to identify factors that will motivate organizational actors likely to engage in OPB. Unfortunately, these recommendations do not address the problem of how to implement organizational policies and procedures that will encourage these positive behaviors.

To do this, governmental organizations must take a strategic view of positive uses of OPB. For example, the National Research Council (1994) suggests several organizational strategies for promoting successful inter-organizational partnerships in sharing data. Organizations must develop policies that encourage taking *shared responsibilities shared commitment, shared benefits*: and *shared control*. These guidelines are reminiscent of Robey, Smith, and Vijayasarathy's (1993) research on the role of conflict and politics on IT implementation. In their model conflict resolution is considered to be an important factor affecting success. The fact that the suggested guidelines are designed to mitigate political conflict suggests a model of the relationship of OPB and implementation success (see Figure 1). In this model an increase in shared commitment and shared responsibilities is expected to increase participation by organizational actors. Further, enabling organizational actors to control the decision making process suggests that those who are participating will also have influence on the outcomes of the implementation process. In turn, the anticipation of benefits being derived from the projects will lead to buy in into the project. If each of these guidelines is followed, conflict should be reduced and the success of the project should be more likely to occur.

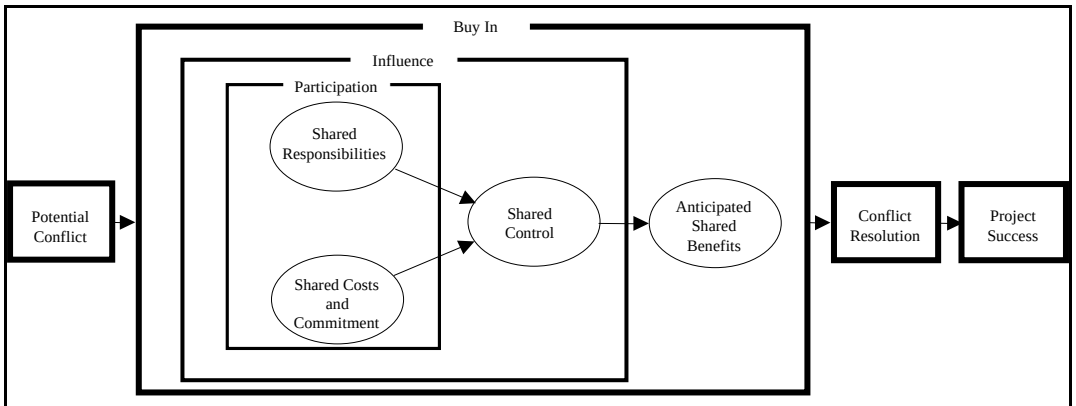

Figure 1. The Role of Political Conflict Resolution on GIS Implementation Success

Although we have not tested this model empirically, anecdotal evidence suggests that the model accurately describe the implementation process. For example, Klein (1995) reports on a successful collaborative development project initiated by Tijuana and Ensenada, Mexico that resulted in a jointly developed and owned GIS. A factor identified as being critical to the success of the project was early efforts to identify and quantify the shared benefits of the system.

Conclusions

In addition to its widely reported applicability to the management of specific projects and resources, GIS data has the inherent capability of serving as the basis for an integrated decision support system at the highest levels of government in developing nations. The natural relationships created by the spatial elements of GIS data provide connectivity that is not

naturally available in conventional systems. Further, modern hardware and GIS software make this connectivity availability with relatively small investments.

These benefits are offset, however, by the lack of existing geographic data for many areas of the world. Further, developing data is often costly and difficult. On the other hand, there are strategies available to reduce the cost or increase the efficiency of data creation and it is not necessary to have universal coverage before benefits can be realized. Finally, GIS data represents a national resource that should be cultivated and supported. Policies should establish standards for data development and careful infrastructure decisions.

References

References available upon request from the first author (lwest@bus.ucf.edu).