Geographic Information Systems for Urban Planning and Management in the Caribbean: Finding the Right Approach

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While the tools offered by geographic information systems are increasingly used to support urban planning and management in developing countries, experience has shown that 'one size does not fit all' and that implementation policies and strategies must be tailored to the local context if they are to be effective. This paper focuses on GIS experience in the Caribbean Basin. Campbell and Masser's distinction between implementation approaches - technological determinism, managerial rationalism and social interactionism are used in this assessment of GIS experiences. The paper concludes with policy recommendations to support more effective use of GIS tools for urban planning and management in the region.

1. Introduction

In recent years geographic information systems (GIS) have emerged as a key tool for urban planning and management throughout much of the world. This is the case even in very small countries with limited financial resources, such as Belize, where a first rate GIS facility is in operation. In most cases GIS services are introduced to meet two primary goals: to improve the quality of decision-making and the efficiency of day to day operations. However, the experience that institutions have had with GIS is extremely varied and many projects have been simply abandoned after a costly initial effort. Challenges in GIS implementation in the developing countries have been widely reported (Karikari et al, 2005; Saladin et al, 2002; Mohamed and Plante, 2002; Nasirin et al 2003; Syed et all 2003; and Erik de Man and van den Toom, 2002.

This paper employs a conceptual framework that has been advanced by Campbell and Masser (1995) to assess the implementation approaches in Caribbean countries Following a brief presentation of the conceptual framework, the paper focuses on the specific challenges that

are faced by Caribbean countries when introducing GIS, presents a categorization of the range of implementation approaches in the Caribbean, offers several specific examples that illustrate common experiences, and concludes with recommendations for future implementation strategies.

1.1 Implementation Approaches

In seeking to understand the reasons why some institutions are more successful than others in introducing and using GIS, researchers have found that it is helpful to distinguish between three main implementation approaches: technological determinism, managerial rationalism and social interactionism (Campbell and Masser, 1995).

The appeal of technological determinism approach lies in the dramatic influence that technological advances appear to have on production techniques and social relations, as noted by many observers, including Karl Marx (1874). In its extreme, the term technological determinism suggests that advances in technology lead inevitably to predictable organizational and social changes (McCormack,

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1994). Many, if not most, of these changes are simply considered *progress* – a term that suggests the change is positive (Haufschild, 1997). In the early years of GIS this perspective dominated. Vendors offered increasingly tempting packages of hardware and software that were purported to be indispensable to efficient municipal planning and management and insufficient attention was given to the specific organizational needs of the purchaser (Campbell and Masser, 1995). Often, uncritical acceptance of GIS technology extends to its products and result in new procedures and standards being justified on the basis that the technology is most amenable to this way of doing things (Haufschild, 1997).

In contrast, the managerial rationalist approach seeks to adapt new technology to organizational needs. Here it is assumed that a logical approach to problem and need assessment will result in a specific plan that will enhance the effectiveness and efficiency of the organization and lead to a rationalization of human affairs (Ellul, 1964). In practice, new technology is selected and introduced wherever it contributes to organizational goals and quantitative measures are devised to assess progress towards each goal. While humans, not technology, are in charge, the worth of employees is measured in production units and the "structures and hierarchies of the technology are reflected in the organizational techniques used by management" (Haufschild, 1997). As individuals are assumed to make rational choices, a well organized system will be consensual and result in smooth operations (Kling, 1996). This perspective has predominated over the past decade and has led to specific, well-trodden recommendations concerning GIS implementation that move from Needs Assessment to System Design, Development, Operation and Review (Arnoff, 1989; Huxhold, 1991, Vastag et.al, 1994).

Finally, the social interactionism approach views the organization in political, social and psychological terms as inter-related systems (Changler, 1997). While technology remains important, its importance is manifest in the ways that it shifts power structures within the organization. These shifts result from the decision-making processes of individuals at all levels of the organization who seek to reposition themselves to adapt to and take advantage of new social interaction patterns within the organization that are framed in part, by the new technology (Blumer, 1990). Further, as humans seek stability, or at least predictability, many employees are resistant to new technology that requires significant change in their work habits and requisite skills (Eason, 1993; Haufschild, 1997). Given the importance this perspective attributes to individual agency, the communication and social skills of managers in charge of introducing GIS to the organization become more important than their technical skills (Buchanan, 1993).

As Haufschild (1997) notes these three perspectives represent to some extent an evolution of attitudes towards the implementation of GIS from technological romance to rational goal-oriented management and finally to a more profound consideration of the interactive relationship between technology and social interactions within an organization. Evolutionary or not, all three attitudes are most often present during each and every GIS implementation and the balance between them greatly influences the success of the new facility.

2.   GIS in Cities of Developing Countries

It must be acknowledged that there are significant developmental differences among cities in the developing countries. Nonetheless, there are some common features. These include: rapid population growth, dependence on a resource based economy, poor environmental conditions, a lack of reliable, current and accessible data, low average income accompanied by immense income disparities, scarce government funds, significant reliance on the informal economy, a limited pool of skilled and well educated individuals, limited education opportunities, and dependence on external funding.

While many of the techniques associated with GIS implementation would be helpful in addressing development issues, the characteristics presented above lead to a different array of GIS implementation challenges than is the case in most 'developed

countries'. While a city in the 'developed' world would attempt (with varied success) to use GIS technology to plan infrastructure investments and direct new development away from environmentally sensitive areas, rapidly growing cities in the 'developing' world are less prepared to use technology to deal with urban growth issues and often experience a radical decline in living standards.

Countries in the Caribbean region share most of the characteristics of developing countries, noted above with the exception that overall population growth is somewhat offset by out-migration. Nonetheless, high urbanization rates coupled with the shift in land consumption patterns that has accompanied increasing automobile use throughout the world is resulting in significant expansion pressures in urban areas (see Wolfe and Brown, 1999, for an analysis of land consumption patterns in Trinidad).

Specific characteristics of cities in the Caribbean that must be taken into account when considering the introduction of GIS facilities include: Politics and bureaucracy, legislation and administrative procedures, and education and retention of skilled staff.

3. Politics and Bureaucracy

Most Caribbean countries achieved independence from colonial powers peacefully within the past 50 years. While the decolonization process certainly had dramatic moments before, during and after the event itself, the overall process was gradual and many of the characteristics of the bureaucracy during the colonial regime have been retained (Shoman, 1987: 28). Of particular interest to this paper are the retention of heavily centralized government and planning structures, very weak local authorities, and the presence of powerful national agencies that are charged with managing infrastructure.

The introduction of GIS technology in post-colonial governments that have retained many centralized structures upsets the power balance among civil servants in a given agency, between agencies and between government and the public. Some individuals resist the new technology and its accompanying administrative

changes actively or passively with the hope that the proponents will simply recognize that they cannot win. Others try to reposition themselves as gatekeepers of the information and skills that are required to support the system. Often entire agencies, as was the case in Trinidad as described below, adopt strategies that are intended to position their organization in a more powerful position relative to other agencies.

Concern with the ramifications of introducing new information systems is often felt at the highest level as these systems effectively make decision-making much more explicit and transparent. GIS renders the effectiveness of government policies much more explicit and transparent by providing better access to up-to-date information that may be used for monitoring purposes, thereby sharpening political competitiveness.

4. Legislation and Administrative Procedures

Many post-colonial countries in the Caribbean are only now beginning to significantly change land use and planning legislation that had been in force during the colonial period. Typically this legislation calls for a master planning approach that focuses on land use patterns and infrastructure requirements over a specific time period. More modern legislation incorporates measures to deal explicitly with social, economic and environmental issues, provides for public input on controversial issues and favors a process-oriented approach to planning over the product orientation inherent in the master planning approach. This modern legislation works well in the sea of current and accurate information.

By improving access to information for the public and private sectors, a GIS facilitates a more iterative, process-oriented approach to planning. A GIS facilitates a 'what-if?' approach to planning wherein the consequences of alternatives can be explored during public workshops. This effectively shifts the role of the planner from someone who manipulates information in the background using obscure models and decision-making rules to that of an effective communicator who help stakeholders

understand not only the issues but the methods and decision-making rules that are being used.

A GIS may also greatly facilitate routine, day-to-day administrative chores. For example, the maintenance of up-to-date property records is a major concern in many cities. Frequently, paper based records are out-of-date and it is very difficult to examine spatial and temporal ownership use and property value patterns.

5.   Data and Equipment

Cities in post-colonial countries often have access to an incredible amount of information that is routinely collected when administrative forms that had been designed to maintain central control are completed for a wide range of transactions on a daily basis. This information, however, is rarely used for decision-making unless it is entered into a digital system. A well-designed GIS facility may incorporate the information contained in administrative transactions and thus make it accessible for analytical uses.

While hardcopy topographic maps of the Caribbean are available, they are often outdated. There is a gross lack of maps on other features such as property ownership, land value and land use. Recently many countries have embarked on new mapping program using modern technologies. The introduction of GIS is, however, hampered by a lack of related information technology infrastructure: high-quality and inexpensive telecommunication service, a stable electricity supply, and high speed and broad-band internet access.

6.   Education and Retention of Skilled Employees

The lack of education programs that explicitly deal with local urban development problems and are cognizant of local administrative and planning practices often limits the availability of well trained staff and, therefore, effective municipal planning and management. In the Caribbean, this need is being met by a graduate program in planning and development at the University of the West Indies, in Trinidad and an undergraduate program at the University of Technology, in Jamaica. However, despite the availability of these programs there is a tendency

among professionals to valorize the methods and procedures that are practiced in North America and Europe. This tendency is unfortunately augmented when new technology is introduced as pertinent experience in its use most often resides in more industrialized countries. Care must therefore be taken that a GIS does not transfer a world-view and a set of methodologies that do not respect local culture along with the technology.

Retention of trained personnel is a problem in all organizations and most especially in developing countries where salary levels are lower. This is amply illustrated by a project in Belize where among 12 people who were trained to manage databases only 2 were available for employment on the project a few months later. The others were in more financially rewarding positions in the private sector or had immigrated to the United States (Brown and Wolfe, 1997).

7.   GIS Implementation Approaches in Developing Countries.

Significant investments have been made in the implementation and use of GIS in the Caribbean. International development agencies, such as the Canadian International Development Agency (CIDA), have provided aerial photographs, satellite imageries and training to help local governments use modern, cost effective techniques to support their sustainable development agendas. To date, however, very little progress has been made and few tangible results are available to demonstrate the effectiveness of these investments. One major reason for this deficiency is the sporadic and uncoordinated approach to the implementation and uses of GIS resources.

The implementation and use of GIS facilities in developing countries rarely follow a holistic strategy. A reactive rather than pro-active approach has evolved. Two factors account for this - the lack of an understanding of the need to coordinate technology-driven solutions with capacity building; and the high capital and human resource investment which must be injected in order to obtain maximum benefits. Despite these factors, GIS technologies are slowly but steadily penetrating the region and are increasingly relying on natural and physical

resource management. Four patterns of GIS implementation have evolved. These are project-domain, departmental-domain, national-domain, and regional-domain approaches as shown in Figure 1. This categorization does not include two of the domains of GIS that have been most active in Canada, the United States and Europe – municipal and inter-municipal information systems. The fact that these domains are largely inactive in the Caribbean reflects the high degree of centralization and sectorialization in government and administration, as noted above, and the very limited functions, and even more limited resources that are afforded to municipal and inter-municipal structures in the region.

8.   Project-Domain Approach

GIS implementation with the project-domain approach focuses on a single purpose, such as the production of local-area land use plans and flood hazard mapping. Hardware and software resources are acquired to provide specific support for the project objectives. These projects are often initiated and undertaken by consultants with limited local involvement. On completion of the project, GIS products are provided to the local agency and the hardware and software used for the project are either left with the local agency or returned to their country of origin depending on the pre-project arrangements.

The Organization of American States (OAS) in 1987 commissioned the University of Pennsylvania to undertake a Natural Resources Assessment for Agricultural Development Project in Antigua. The project used a GIS to prepare digital databases. The project, however, did not provide for capacity building and the computer resources used were returned on completion of the project (System Caribbean Limited, 1994). In Nevis, a Canadian engineering firm undertook a National Park Suitability study using the SPANS GIS software. The databases involved were developed in Canada. Local involvement was limited to the cartographic presentation of digitized data and generation of simple queries.

The value of project-domain GIS initiatives is quite limited as they often lack capacity building and do not enhance local technical resources. Nonetheless, they may help familiarize local counterparts with the components and utilities of GIS and provide relevant experience for similar projects in the future.

The real advantage of the project-domain approach is that it minimizes the difficulties inherent in all three of the implementation perspectives highlighted by Campbell and Masser (1995). As foreign-based project teams with significant international experience typically apply GIS procedures that have been used on other projects by professionals in their organization, they are familiar with the technology and the relationships between players are well known and not likely to be disturbed by project activities. Further, the focus on a single project makes it relatively easy to devise a rational management structure as data gathering is more focused.

9.   Departmental-Domain Approach

The departmental-domain approach improves on the scope of the project-domain approach by including capacity building. Instead of focusing on a specific project objective, the GIS is designed to serve encompassing departmental goals and functions. In a number of Caribbean states agencies project-based GIS facilities have developed into departmental-domain. These agencies have committed a significant portion of their budgets to GIS technology, data automation and related capacity building. They have also become points of reference for other agencies that are planning to invest in GIS resources. For example, the Water and Sewerage Authority (WASA) of Trinidad and Tobago that initially began with a modest digital mapping activity in support of its engineering functions, now uses GIS to support a much wider role in the Authority.

CIDA has financed departmental-domain GIS programs in three states of the Caribbean: St. Lucia, St. Vincent and the Commonwealth of Dominica. These initiatives involved the acquisition of computer hardware and software, development of databases and the training of local staff. GIS is now being used for local area planning and environmental protection in these countries (Johnston, 1994).

In addition, the UNDP/UNCHS has provided GIS support in the Physical Planning Units of the following Caribbean states and territories: Grenada, Anguilla, St. Kitts and Nevis, Montserrat and Antigua. This support has enhanced the production capacity of these state agencies in the performance of their functions (Galema, 1994).

The introduction of a department-wide GIS facility is much more problematic than the situation for a project-based GIS. In large departments there may be many decision-making units with somewhat different priorities, expertise, methodologies, data requirements, relationships to other departments and degrees of responsibility to the public. Frequently departments have difficulty dealing with the issues raised by Campbell and Masser (1995) with respect to all three implementation perspectives. Vendors often push technology that is not needed or that is ineffective on internal committees that have limited experience with GIS implementation. The new system often requires a radical restructuring of data acquisition arrangements, data flow and decision steps. These changes require substantial adaptation on the part of individuals within the department who must acquire new skills to play an effective role and worry about their place within the organization. In addition to devising a rational plan for hardware and software purchases, data flow, decision-making protocols and so on, careful consideration must therefore be taken of the structure and culture of the organization.

Implementation of GIS facilities in separate departments without interagency coordination may well result in considerable duplication both horizontally and vertically.

TABLE 1: Selected Departmental-domain GIS Facilities in the Caribbean

- Town and Country Department, British Virgin Island
- Archibald Research Centre, Dominica
- Physical Planning Department, Nevis
- Physical Planning Department. St Lucia
- Coastal Zone Management Unit, Barbados

- Water and Sewerage Authority, Trinidad and Tobago
- Town & Country Planning Division, Trinidad and Tobago
- Guyana Natural Resources Agency, Guyana

10. National-Domain Approach

GIS implementation at the national level is usually introduced to reduce redundancy in the acquisition and the use of GIS resources throughout the country. This approach, which is still in its infancy in developing countries, is holistic in nature and strives for a comprehensive approach to data collection, training, and development of applications that span departmental lines.

Belize, Jamaica and the British Virgin Islands are ahead in the development of a national GIS. Jamaica has instituted a National Land Information Council. Belize has a National Land Information Centre, and BVI has established the post of a National GIS Coordinator. Data sharing and pooling of resources towards developing a national digital database is becoming a norm in these countries and territory. Efforts are underway in other countries to develop nationwide spatial databases and provide data sharing among all agencies.

While the development of national databases facilitate data sharing across agencies it requires years to develop and may not have all the attributes that are required by certain agencies or localities within the country. In large countries with decentralized municipal planning and management authority, such as Canada, a national-domain approach that would support decision-making simultaneously at national, provincial, regional and local levels would be difficult to design and politically impossible to implement. Alternative approaches that allow each decision-making unit some flexibility in system design yet ensures that data may be transferred easily between agencies may be more effective in some instances.

11. Regional-Domain Approach

The regional-domain approach is currently receiving consideration in the Caribbean. The first experiment in the development of such an

approach in this region was initiated in 1990 through the designation of the Institute of Marine Affairs (IMA) as the Regional Centre for Remote Sensing by the Caribbean Community (CARICOM). The Centre received financial support from the CARICOM Secretariat, the OAS and AMOCO Trinidad Oil Company. The Centre has worked on a number of regional projects such as: *"Evaluation of the Resources of the Coastal Zone and the EEZ of Trinidad and Tobago"* and the skills and institutional capacity to analyze high-resolution satellite imagery using remote sensing software has been acquired. Increased funding and the participation of personnel from other parts of the region are, however, urgently needed to fully develop the capability of the Centre (Griffith, 1995).

World Bank/GEF funding in support of the Caribbean Adaptation to Global Climate Change (CPACC) project is another example of a regional approach. It involves the provision of computer hardware, software, databases, and training to 12 Caribbean countries and is a major contributor to GIS utilization in the region.

A regional approach to GIS implementation is particularly appropriate in situations where a large number of small countries with limited resources face common development and or environment problems. As the Caribbean meets these criteria and moreover has several well established regional institutions, such as CARICOM, this approach is promising in the region. While it would be impossible to consider introducing a comprehensive GIS system that would be used for regional, national and local decision-making, there is much to be gained by developing compatible systems that can be scaled to different levels of intervention and transfer data between countries. Standards for the collection, representation and storage of data that are shared across the region would certainly be helpful in providing comparable information and building robust data management institutions in each country.

A regional-domain GIS can avoid some of the difficulties noted by Campbell and Masser (1995) that may be encountered by departmental and national systems by maintaining a certain level of abstraction. Data standards are best set by technical committees while the selection of which data to use and for what purpose may well need to vary between jurisdictions both vertically and horizontally within the region. These regional technical groups essentially set the table for national and local stakeholders to engage in the vigorous job of decision-making.

11.1 *Implications of the Evolving Development Pattern*
The evolving implementation approaches can best be described as cautious. The strength of these approaches is that they improve on past mistakes and rely on the experiences of others in the shaping of its future. They have the ability of reducing investment risk by building on existing initiatives. The various GIS initiatives currently implemented in the Caribbean has provided learning opportunities. States and private agencies proposing to acquire GIS resources can undertake inter-state visits to gain and share experiences. The small size of the states also provides opportunities for testing and implementing GIS concepts in a relatively short time and with minimum risk. Opportunities also abound (although not yet tapped) for the sharing of technical and human resources.

This low-risk approach is, however, not ideal for a technology-driven solution. GIS hardware and software are updated and revised at short notices. Investment at the project-domain, most often, may not fit into department-domain requirements. The technical resources used at the project-domain may be quite inadequate for large-scale implementation. New training and new database design may be required. Agencies that initially invested in low-end GIS may soon realize its limitations with respect to their department's needs and thus invest additional capital to acquire multi-user computer workstations for an upgraded version. Disparate development of departmental-domain GIS can lead to uncoordinated national GIS plan. In Trinidad and Tobago, there are over ten departmental GIS sites that have nothing in common beyond the use of similar software. When departmental goals are allowed to flourish without any form of national coordination and collaboration, the possibility exists that those departmental initiatives may become too expensive or impossible to evolve into national-

domain. The need for GIS standards must be appreciated and developed for this to happen.

12. Conclusion

This brief overview of the range of experiences with GIS facilities in the Caribbean Basin highlights a number of concerns that should be addressed to ensure that these facilities meet the expectations of their proponents. Of these, one of the most critical concerns is the need to take into account the structure and social climate of the institutions that are expected to play a role in the new system. While the usefulness of GIS technology once appeared to be self-evident, experience has shown time and time again that the ways that people and institutions interact with each other greatly influence the success of projects and must be taken into account. New information processing techniques and procedures effectively shift the balance of power within and between institutions and set in motion a variety of coping strategies.

The importance of institutional relations coupled with differences in the information and analysis requirements of professionals who are concerned with different urban phenomena such as surveyors, engineers, economists, demographers, police and fire prevention specialists, sociologists, architects and planners make it difficult to imagine a single comprehensive system that meets everyone's needs. Nonetheless, it is important to have a common spatial reference system and data protocols that facilitate the exchange of data and collaborative work. Ideally, this would be developed at the regional level in the Caribbean Basin due to the limited resources of each country and the extent of common problems they face. The lack of such a system has resulted in considerable duplication of effort in many countries.

Experience has also shown that internationally funded GIS projects must include a substantial local training component if there is any intention of maintaining the facility on an ongoing basis. This would ideally be done in collaboration with existing academic programs in the region which offer training in the full range of GIS applications. A further difficulty is the retention of trained staff, a problem that can only be addressed by ensuring at the outset that the project has sufficient resources and growth potential to retain the interest of skilled personnel.

The role of contractors affiliated with international agencies is also critical. Too often, international experts parachute into a country on a mission and produce reports that do not offer a nuanced appreciation for the local context or provide adequate time for local collaboration. Capacity building is much more effective if foreign resource personnel have extended stays, as was the case in Belize, during which they work along with local partners on projects. In any case the projects must be driven by the priorities of local stakeholders if the results are to be of any practical use.

While in some localities the infrastructure that is needed to support the full range of GIS applications, such as a reliable power supply, hardware and software support and scanning, printing, plotting, telephone and internet services, are not readily available, these constraints will likely be eliminated in the next few years. Likewise, the lack of maps and data in digital form, a problem that has led to cost overruns throughout the world, is becoming less significant with the ready availability of high resolution satellite images and other data sets.

The limited role and resources of local municipalities in the Caribbean greatly impedes the development of effective GIS at this level. This is unfortunate as it is at this very level that the problems and opportunities poised by everyday life can be best addressed. When national agencies assume responsibility for local municipalities, as is most often the case in this region, a sectoral approach may develop with strong vertical links and weak horizontal, interdisciplinary links.

Clearly a well conceived GIS facility can support a wide array of applications that contribute to more effective decision-making among professions at all levels of government. Further, the flexibility of the technology greatly facilitates a more iterative approach to planning that provides an opportunity for local residents and community groups to be more actively involved in decision-making on an ongoing basis. The interdisciplinary platform that a GIS

provides, coupled with the 'democratization' of planning that the technology facilitates, may well contribute in a substantial way to the development of cities that rise to our expectations.

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