Considerations from the Development of a Local Spatial Data Infrastructure in Brazil

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1 Introduction

Even though vendors and consultants are always eager to announce the potential benefits of employing geoinformation technologies in areas such as local government, the actual measured impacts of investments in this direction are not as easily assessed, particularly in the case of developing countries. Surely, there are some successful experiences in the deployment of GIS and other geoinformation tools, but widespread adoption and consistent strategies for the sustainability of these efforts are quite rare.

After about fifteen years since the first GIS technological tools arrived in Brazil, much can be learned from observing successes and failures among local GIS implementation projects. Many of these efforts were not idealistically meant to incorporate the spatial dimension to some of the most critical aspects of local government, such as social policies, urban planning, tax collection, environmental problems, and others, but were rather geared towards more immediate goals, such as revenue increase.

This position paper intends to show, in a historical perspective, that the breadth of scope and the assurance (or not) of strategic investment have had an impact in the success and in the demise of urban GIS projects in Brazil. Our focus is on the best practices in this field, mostly observed during the evolution of the GIS deployment project at the city of Belo Horizonte. Since its inception, demand for spatial information, both from most city departments and from external agents, has caused this project to evolve towards a local spatial data infrastructure. We will also discuss the current research agenda in this field, from the standpoint of the sustainability of current efforts and their spreading to similar situations.

2 Belo Horizonte: From Mapping to GIS to SDI

Belo Horizonte, the fourth largest Brazilian city, has a population of more than 2.2 million people spread over 335 square kilometers, and is the center of a metropolitan area that houses around 3.5 million people. Belo Horizonte municipal administration's GIS project was conceived at a time when Brazilian local governments had just received a wide range of new responsibilities, after the approval of the country's new Constitution, in 1988. Various public services, such as health, basic education, water and sewage, energy, transportation, and traffic were transferred from other levels of government to the municipalities, along with regulations and standards that placed additional pressure on them to be more responsive towards the demands of the citizens. Municipal governments were also expected to be much more accountable and transparent, providing detailed information to the public in order to allow the effective exercise of the democratic right of participation.

Belo Horizonte's GIS development effort has started in 1989, and is continuously evolving. It is widely recognized at the national level, for its pioneering nature and its innovative proposals, which gave priority to social applications, including education, health, transportation, traffic and environmental control, among many others. Throughout its history, Belo Horizonte's GIS has received awards, has been widely presented in the form of invited lectures at many events nationwide, and has generated a body of over 200 publications, including dissertations and theses, academic papers with technological and methodological innovations, conference papers about applications development, and technology dissemination articles[1].

In the early nineties, most other GIS projects were almost exclusively driven towards revenue increases, following a sales pitch presented by many vendors and consultants. According to these "specialists", deploying a GIS would cause enough revenue increases to pay for the entire technological investment in a very short time. In fact, methodological flaws and lack of consistent updating caused cadastral bases for taxing purposes to be quite outdated, and any data checking or updating effort would cause revenue increases anyway – regardless of the use of GIS. For that reason, most urban GIS projects in Brazil were led by the tax collection department, rather than by the urban planning department, or even by an IT department.

In Belo Horizonte, the GIS was developed at the municipal IT company (PRODABEL), which was also the responsible for the city's cartography. This unusual scope of activities enabled Prodabel, early in the project, to form a team of specialists in several IT areas (databases, information systems, computer graphics) as well as in fields such as urban cadastre, cartography, surveying and others.

Concern on multiple uses of the data was present early on the project. Ensuring the level of investments and political support required to push the project forward, at a time when this technology was largely unknown, required project managers to propose applications in many different areas. Project managers were also able to convince decision makers throughout the administration that a solid basemap was required in order to provide adequate support for the thematic applications.

With this, Belo Horizonte's GIS was faced early on with three important challenges: (1) building a general-purpose database, (2) developing a wide range of applications, mostly in social fields, and (3) keeping this database up-to-date, as required by the applications.

The first challenge is directly related to research in topics such as data transfer standards, evolving towards interoperability, and then on to semantics and ontologies. This caused part of Prodabel's GIS team to evolve into a research team, continuously seeking innovative approaches and solutions to all these themes, often in cooperation with universities and research centers.

The second challenge regards arguably the most important aspect of GIS as a technological tool, which is its interdisciplinary nature. From this, the involvement of specialists from each application area was required, thus forcing the establishment of strong connections between Prodabel's original GIS team and thematic specialists in each of the city's departments, particularly in health, education, sanitation,

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[1] For a partial listing of such publications, visit `http://www.pbh.gov.br/prodabel/cde`

transportation, planning and licensing. In each of these areas, GIS became a tool geared towards technical activities, used directly by technicians, with IT and basemap support by Prodabel.

The third challenge required an approach that is neither academic (as the first) nor integrational (as the second). Updating such a varied database (currently comprising over 6 million objects, distributed through over 300 object classes) requires a strong coordination of efforts and cooperation with external agencies (utility companies, state government departments, federal institutions, universities, and others). In turn, this drive towards cooperation provokes an interest in data sharing among the municipal administration and these external actors, which expands even more the range of GIS data and applications, thus forming a virtuous circle, leading to increased data quality, interoperability, and scale gains.

We observe that most GIS projects fail for not achieving either one of these challenges. This is not to say that every single-theme GIS fails, but since data sharing and cooperation are bound not to occur, the financial and political structure must be much stronger for the project to succeed. In developing countries, lack of financial support, political discontinuity, fuzzy goals, and deficient planning have been pointed out as the source of most failures. It is clear to us, after over 13 years of urban GIS development and maintenance, usually under less-than-ideal circumstances, that a strong and up-to-date database, on which multiple applications are based, and on which demands from several institutions are constantly placed, tends to receive continuing political and financial support, and is capable of achieving its own technological evolution. This description, in our point of view, corresponds precisely to the definition of a spatial data infrastructure.

3 A Research Agenda

Considering the arguments presented at the previous section, some research challenges come to mind. We’ll next provide a general description of each one of them. However, it is important to keep in mind that the observations presented at the previous section should also become a research theme, possibly in administration or information science, in order to develop a broader view of the subject.

From Data Interchange Standards to Interoperability to Semantics and Ontologies. Early in the development of GIS, the lack of neutral data interchange standards was an issue, something that prevented cooperation and data sharing. Later on, with initiatives such as the creation of the OpenGIS Consortium, the focus changed towards interoperability, i.e., the drive towards data sharing among heterogeneous networks, and among products from various vendors. However, semantic differences in data modeling and in the development of databases have led to a more profound discussion, on data semantics and related subjects. One of these subjects is nowadays a much debated field, over which agreements on common conceptualizations are researched. Ontologies, and ontology-based information systems, are changing the way we design and implement knowledge-based applications.

Ontologies of Urban Geography. Particularly in urban applications, we see the need to extend existing agreements and conceptualizations on the semantics of common urban landscape elements, such as addressing, land parceling, and others, thus forming ontologies of urban geography. Many of those elements change rapidly, and current information systems strive to keep the last version of each object. This field intends to capture temporal versions of objects, along with including in the modeling and in the representation the causes and the process by which changes take place. This is to be achieved through through *ontologies of change*.

Information sharing in distributed spatial databases. Once semantic issues are solved, or minimized through the use of resources such as metadata, active sharing of information can take place. This is not limited to file exports and imports in a common format, but intends to allow access to entire databases through the Internet. The OpenGIS Consortium has defined standards for Web Feature Services, through which applications can dynamically reach the data they need at servers which are distributed throughout the net.

Spatial data warehousing and spatial data mining. As information volume increases, interest on spatial data warehousing and spatial data mining become indispensable. Conventional data warehousing limits itself to alphanumeric data, failing to consider the spatial dimension – unless it is explicitly coded as attributes in data tables. Since as much as 80% of local government databases can have be spatially-related, taking the spatial dimension in consideration is extremely important. However, issues on spatial data representation across multiple scales have an important role, thus leading to connections with research on multiple data representation and cartographic generalization. Modeling techniques for spatial data warehousing must also be specially developed, like in the case of data modeling, since conventional techniques fail to capture much of the semantics of spatial data.

Internet access to spatial information for the common citizen. One of the major issues in current GIS is the learning curve of most tools. There is some progress in the development of spatial data access over the Internet, but the quality and effectiveness of human-computer interaction is still a complicated point. Spatial data users can potentially have any kind of background, and while visualization makes it much easier for users to understand the meaning of data, inappropriate use of such tools can mislead a common citizen into getting the wrong message. New visualization techniques, combined with recent Web standards such as SVG can help.

4 Topics for Discussion

Considering the initiative for cross-learning between SDI and II, we consider there are many topics on which discussion can evolve. From our experience, many methods and techniques that apply naturally to conventional data are not as well suited to spatial data. This has forced research in SDI to develop advancements in data and knowledge representation, with support from advances in artificial intelligence, databases, software engineering and other computer science subjects, most of which could greatly influence II. We observe that SDI is probably more advanced in capturing and representing aspects of a dynamic and constantly changing world, with an emphasis that makes us think on the growing obsolescence of conventional information systems, in which updating causes relevant information to be lost forever.

Furthermore, we notice that organizational aspects of information management are still important issues both to II and SDI. Perhaps cross-learning should extend to other areas of knowledge, including information science, business administration, geography and others, from which SDI and II could learn and interact.