PLAN 657 Research Paper:

Open source GIS to support community-based organizations

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Contents

I. Local communities and their spatial problems

The term local community is very broad so that it encompasses very different conceptions and definitions depending on the context and the people using it. Therefore, it is important to first explain what we refer to when we use this term and what it implies. Originally, the definition of a local community had geographic roots. It refers to any group of people who are part of the same geographic area. The people belonging to the same local community live nearby so that they share some resources such as lands, buildings, and services. Therefore, there are strong spatial interactions between people, which can raise conflicts or initiatives of collaboration. These interactions are increased by the rapid changes in land use, demographic, socioeconomic, and infrastructure conditions of the communities across North America (Ghose, 2001, Esnard, 2007). Therefore, local governments and non-governmental organisations (NGOs), to whom the solution of these issues has been delegated (Fulcher, Barnett, & Barneet, 2002), try to find solutions to tackle these problems. One main trend is to promote citizen activism through local opportunities including neighbourhood revitalizing, local planning, and environmental initiatives. To get involved in these opportunities, local people gather into different type of organizations such as community-based organisations, community development corporations, and neighbourhood associations (Elwood & Ghose, 2001). These organizations can be either stable to support long-term interests in a neighbourhood or transitory to support a precise goal. All these different kinds of organisation will be commonly denominated as community-based organisation (CBO) in the remainder of this paper.

It is important to note that with globalization and the generalization of the IT, the borders of geographic areas are blurred and the notion of distance is reshaped. Nowadays, people's actions on one side of the planet can have impacts on the other side of the planet. Therefore, the definition of a local community can be extended to a larger scale. In this case, the community-based organizations are groups of people who share interests and who gather to promote their ideas through organizations.

The actions of the CBOs that deal with these spatial issues can be enhanced by the use of GIS. GIS technologies can help CBOs in many ways according to their needs and the context in which they operate. Therefore, the potential of GIS technologies to meet CBO needs will be organized in a framework.

II. Framework of community needs in term of GIS solutions

The developed framework does not look to characterize all the aspects of CBOs initiatives like some other frameworks (Sieber, 2006, Carver, 2003, Gene & Frewer, 2005). This framework focuses on the community needs and the potential of the corresponding GIS technologies to meet them. The CBO needs differ in their level of complexity. They may simply want to gather information and communicate or they may want to involve people in decision-making processes. This level of complexity can be characterized by the flow of information between the organization and the public. *Gene and Frewer* (2005) define three different flows between the public and the sponsor. In our case, the sponsor is the CBO and the public is the local people who are not part of the CBO. The first type is a one way flow from the organization to the public: communication. The second one is a one way flow from the public to the organization: consultation. The third one is a two way flow. Furthermore, a lower level of no interaction can be added when the CBOs act without involving local people. These four levels of interaction will be used to structure the needs.

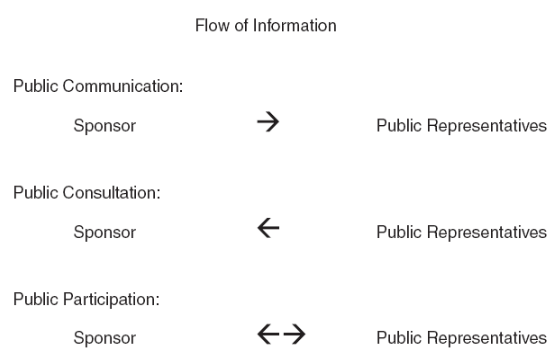

Figure 1: Types of interaction (Gene & Frewer, 2005)

1. Data management and in-house GIS solution

Digital spatial data are now ubiquitous, at least in developed countries, and they have been proven to radically change and improve the speed and the efficiency of spatial information access and handling (Ghose, 2001). Therefore, a basic need that does not imply interaction with people outside of the organization is the management and the analysis of digital spatial data. Besides, being able to handle spatial information is a requirement to achieve more complex goals. Indeed, spatial data have to be gathered, processed, and formatted before being available for analyses and other uses described later. The processing part can include basic geoprocessing such as geocoding, handling of coordinate systems, and cleaning of data. Analyses can comprise some more advanced geoprocessing such as overlay and buffer operations.

To be able to manage and analyse their spatial data, CBOs need appropriate tools. The easiest and most efficient way to perform basic GIS operations for internal purposes is to use a desktop GIS. A desktop GIS is a stand-alone application that is installed on every computer where it needs to be used. It allows for quick and user-friendly spatial data handling and analyses. Therefore, it provides a convenient way to format and produce nice map and to perform in-house analyses. Furthermore, by default, the data is stored locally on every computer or accessed from a shared network. Therefore, CBOs may want to use a database to allow users to simultaneously modify and keep data up-to-date. Finally, needs in spatial data management can differ, especially in complexity, from one organization to another so that the richness of the GIS software has to be adjusted. The required level of complexity is related to the type of the end-users presents in the organization and the task they have to achieve (Gilfoye & Thorpe, 2004).

2. Communication and web mapping

In the first need, access to information is limited to internal use by the organization. However, the organization may want to inform people on specific topics or issues, for instance, the availability and the location of social services in the district or the draft of a new urban development. To refer to the *Gene and Frewer* framework, this is classified as communication since the flow of information goes from the sponsor to the public. Therefore, CBOs need an efficient and affordable way to diffuse spatial information.

In order to enhance the traditional hard copy map, which is seen by a very limited amount of people, organizations can take advantage of the possibility of publishing dynamic maps on the Internet. The map is dynamic in the sense that users can browse the data. However, they cannot modify or add data. The use of web-mapping has numerous advantages to ensure an efficient and affordable diffusion of spatial information due to its flexibility, ease of use, ubiquity (Anderson & Moreno-Sanchez, 2003). First, the Internet offers a way to disseminate information at a very low cost. With a website, the audience can be easily broadened with few resources (Peng & Tsou, 2003). Furthermore, the importance of broadening the audience thanks to the Internet is highlighted by the fact that online presence is becoming more and more similar to the presence in the real world (Zoo & Graham, 2007). Finally, a more technical advantage is the centralization of the maintenance and the development in one place by a limited number of people. This is an important advantage to reduce costs thanks to reduced maintenance time and better skill management. Many examples are available across the Internet, the following presents two of them. The French council of the regional area called Val d'Oise makes a dynamic map available on the Internet for locating cultural and social point of interests[1]. The Italian island of Ischia makes available the location of point of interests including hotels and parking in order to enhance its visibility for the tourists[2].

The use of the Internet broadens the potential audience but, at the same time, it changes it. People using the Internet are usually not the same as the people attending open house. Therefore, it is still important to keep tradition means of communication (Von Haaren & Warren-Krestzschmar, 2006).

3. Public consultation and Web GIS 2.0

Another need that community-based organizations encounter is the collection of local knowledge. Indeed, the importance of citizen participation and the value of local knowledge have been proven to be important for planning and revitalization processes (Ghose, 2001). Therefore, CBOs look to integrate local knowledge to make more informed planning processes. In this way, it empowers citizens by giving them an opportunity to contribute to positive changes in their localities. This interaction has only one main flow of information from the public to the sponsor, which is classified as a public consultation according to the *Gene and Frewer* framework. Indeed, even though the organization has to start the consultation process by presenting the topics, there is often no feedback given afterwards to the citizens.

The Internet is again a great tool to fulfill this purpose. Until few years ago, the use of the Internet to gather information from public was limited due to its lack of interactivity. However, a trend enabled by new technologies recently emerged: the user-generated content, also called Web 2.0. These technologies and concepts were first spread by non GIS website such as Wikipedia and have lately been

[1] Available at http://www.valdoise.fr/
[2] Available at www.ischiamappe.it

disseminated to the GIS world (Sui, 2008). Therefore, a large movement of volunteered geographic information is occurring with website such as Wikimapia and OpenStreet Map. This phenomenon and its associated issues are described by *Goodchild* (2007). Most of these projects rely on the potential of geographic annotation as an efficient way of gathering and presenting information (Hopfer & MacEachren, 2007). The interactivity of the Internet used by GIS techniques gives tremendous opportunities to gather local knowledge. First, it lowers barriers of time, space and face-to-face communication. Indeed, people may not be available at the time of an open house even though they really want to participate. The use of the Internet allows them to give their input whenever they have free time. The same kind of issues exists with distance. People may be away for a certain amount of time and still want to participate. They are able to do so with the Internet. Furthermore, some people have concerns to speak up in public meetings or they may be restrained by influential people. Therefore, participating through the Internet, sometimes in an anonymous way, can help them. Thus, more people participate and the input may be more representative. The use of the Internet to gather local knowledge can be illustrated by projects such as MapChat at the University of Waterloo, Slaithwaite at the Leeds University[3] or the commercial product developed by the company Entera[4].

4. Public participation and spatial decision support systems

The final step in the complexity of the community-based organisation needs is the integration of local people in the decision-making process. This involves a two way communication flows where information is going back and forth during interactive exchanges between the local people and the organization. Such undertakings foster the empowerment of local people and the transparency of the decision-making process. The ways to involve public in the decision making process are numerous. A nearly comprehensive list is made by *Gene and Frewer* (2005). The choice of one method or another depends on the context of the issues at stake and the aim of the public participation. Therefore, the computer systems that can aid these decision-making processes also vary substantially. A broad family called spatial decision support system (SDSS) can be defined which provide various analysis functions to assist users to iterate through different phases of the decision process (Densham, 1999). They were first designed with a single user perspective. Then, they slowly evolve towards group spatial decision support systems (GSDSS) that aid collaborative decision-making which include the public. These systems are described by *Jankowsky & Nyerges* (2001) through the use of the EAST framework or in a practical case *by Jankowski & al* (1997). Recently, more and more GDSS are developed on web platforms in order to

[3] Available at http://www.ccg.leeds.ac.uk/projects/slaithwaite/
[4] Available at http://www.entera.de/

take advantage of the benefits described earlier. This evolution was facilitated by the technological advances of the Internet even though they are still important technical constraints such as bandwidth and the difficulty of developing advanced data processing and visualization functions in a web environment. Spatial decision support tools are very specific and customized according to different contexts so that they cannot be further described in the frame of this paper. Here are examples of two generic types of SDSS. In the case of site selection issues, it can be relevant to use spatial multi-criteria analysis (MCA) methods and its integration with GIS (Jankowski, 1995, Malczewski, 1999). Another type of SDSS is the family of planning support system such as CommunityViz which provides capabilities such as 2D and 3D visualisations, creation and assessment of planning scenarios, simulation of policies (Brail & Klosterman, 2001).

Needs	**GIS solutions**
Data management	In house GIS
Communication	Web-based GIS
Consultation	Web 2.0 GIS
Public participation in the decision-making process	Spatial Decision Support System

Figure 2: Sum up of the framework of the CBO needs in GIS

5. The barriers

Despite the advantages provided by GIS technology to tackle spatial problems, their use is not widespread amongst CBOs. Indeed, several barriers related to their resources and their structures prevent them from benefiting from this technology.

a. Resource barriers

The most obvious and stringent barriers to the use of GIS by CBOs are related to their limited resources. CBOs are based on local political opportunities or volunteering so that their funding is limited. Their limited financial resources have important consequences on their capacities to undertake GIS implementation. First, they cannot afford state-of-the-art proprietary GIS software and the corresponding hardware. Moreover, the staff usually has limited knowledge of information systems and GIS. At most a few people are in charge of the information system or are personally interested in information technologies. Therefore, the steep learning curve of proprietary GIS software constitutes a significant barrier since they cannot attend expensive GIS training to get new skills or hire GIS experts. Another barrier can be access to the spatial data. Even though more and more spatial data are freely accessible in North America, some data required in special contexts can be hard and expensive to acquire. In this case, the institutional and organizational factors, described below, such as experience and networking come into play.

b. Institutional and organizational barriers

Sometimes, even though all the material aspects are in place, the use of GIS by CBOs is not efficient (Esnard, 2007). Moreover, the quality of the CBOs GIS production can vary a lot even though the CBOs have similar material context (Elwood & Ghose, 2001). These two concerns can be explained by organizational and institutional factors. First, the use of GIS has to be part of the organization's strategy and priorities so that it is supported or even promoted. This is a key factor since the success of the implementation of GIS by CBOs significantly relies on their strong motivation. Furthermore, the leadership and the staff have to be relatively stable so that the strategy is ingrained in the CBO practices and formulated on a long-term basis. Moreover, the stability of the organization fosters a good networking and organization experience which are essential factors to access local support resources. These organizational aspects are key elements in the success of a GIS implementation, as much as material ones.

III. Open source GIS, a good solution for CBOs?

The GIS technologies constitute a real asset to enhance different aspects of the CBOs initiatives dealing with spatial problem such as the data management, the communication of spatial issues, and the public participation in the decision-making process. However, the process of acquiring and implementing GIS software and hardware can face barriers that are mainly practical due to low funding, but also organizational. Therefore, the remainder of this paper will study how the open source GIS can lower or break these barriers even though open source GIS have their own requirements and facets that CBOs undertaking GIS implementation have to be aware of.

1. Definition

Open source software can be defined by the following characteristics. They can be freely run for any purpose. Their code source is freely available and can be copied, modified, and redistributed. A precise definition is made by the Open Source Initiative[5] which is a non-profit corporation that creates open source standards. However, many variations of the main definition exist due to different open source licenses. A comprehensive list of all the different open source licenses is provided by their website. The type of license is an important point to examine when choosing a solution because it can state some restrictions to resale or develop proprietary custom extension. Some of the strictest license are defined by the Free Software Foundation[6] which is one of the main actors the open source community. This type of free software has to be differentiated from commonly denominated freeware which are free to use but have proprietary source code. In our case, we will adopt a loose definition of open source software as it has been formulated at the beginning and we will consider freeware separately.

Open source software development relies on a community of volunteer developers so that they have characteristics inherent to their development structure. First, the development community structure is scalable. A project is managed by a core team constituted of the most active developers. Members can be added or removed according to their contributions to the project. The community management is thus transparent. Due to this structure of development, the software is designed in a modular manner with some people undertaking the development of specific functionalities. Moreover, the design of the software and its development process are transparent and answer to the user requests who can take part to the discussion (Ramsey, 2007). Open source software has long been considered to

[5] Available at http://opensource.org/
[6] Available at http://www.fsf.org/

belong to the hacker realms. However, open source has acquired maturity in recent years and has overcome myths related to their quality (Wheatley, 2004). They appeal a broad audience including large private business. Some open source projects such as the web server Apache, the operating system Linux and the database MySQL have proven to be very successful (Wheeler, 2007).

Open source GIS (OSGIS) are part of this large movement and correspond to the characteristics describe above. Although Open source GIS projects are relatively recent, they are now accepted by a large audience with numerous successful implementations (Lowe, 2002). Once disordered, the open source GIS action is getting organized. Some websites centralize the information on the open source GIS movement. The Open Source GIS website[7] and the Free GIS database[8] looks to build a complete index of open source and free GIS related software projects. The Open Source Geospatial Foundation[9] has been created to support the most successful and highest-quality open source geospatial software.

2. The use of open source GIS by CBOs

a. Pros and cons

The main barriers encountered by CBOs which try to use GIS are the complexity and the cost of the GIS software. These two aspects are especially related to commercial software. Commercial software look to be scalable and full featured in order to appeal more customers. However, this effort to quickly develop a piece of software that does "everything" brings some downsides. Many commercial GIS are quite complicated as functions for many different types of analyses are often bundled within a single software application. This complexity leads to expensive software to compensate for development cost and to high hardware requirements to be able to run them (Lowe, 2002). OSGIS can help to tackle these issues.

First, OSGIS have no licensing costs so that the software can be freely acquired and run. It is a huge asset to cope with the limited funds of the CBOs. Furthermore, they do not need long term financial commitment so that it is easier to make a prototype and start an initiative. Over the longer term, this can reduce the extra costs of "vendor churn", for instance, paying to migrate to a new version or to get extra support (Wheatley, 2004). However, license costs are not the only costs of acquiring and deploying software. Indeed, it will be more relevant to compare the total cost ownership (TCO) which includes the cost of training, maintenance, extra development time, and support. The comparison of TCO between

[7] Available at http://opensourcegis.org/
[8] Available at http://freegis.org/
[9] Available at http://www.osgeo.org/home

open source and commercial software has no simple answer and depends on the context. However, a main principle can be established: for small organisations such as CBOs, the cheap price to acquire an OSS is essential especially on a short-term basis (Holck, Persen, & Larsen, 2005). Besides, other aspects of OSS described later can reduce the TCO. The price, although essential, must not hide the other assets and drawbacks of the open source GIS. As explained before, the open source movement is not only the production of free software, but also a way of envisioning the software development. Therefore, the whole process of implementation, not only the acquisition, but also support, maintenance, customization is also relatively different from commercial software.

One of the main drawbacks of the OSGIS is their lack of out-of-the-box features. Indeed, commercial software have considerably more ready-to-use features and OSS users may need to shuffle different tools to reach the same level of feature richness or reinvent the wheel to make basic functions available as it can be seen in some research articles (Caldeweyher, Zhang, & Pham, 2006). However, the numerous features of commercial GIS can be overwhelming for a non GIS-literate user. Therefore commercial GIS require staff with a GIS expertise whereas people with simple IT experience and skills can get along with OSGIS. They are even described as simple to install, to learn and deploy by Moreno-*Sanchez & al* (2007), easy to set up (Lowe, 2002). This is an important asset for CBOs lacking GIS expertise. However, this point is rather stated than demonstrated by the authors and this statement is related to the maturity of the OS project and it must be examined on a case by case basis as it is done below. Furthermore, another advantage of the OSGIS that can tackle the problem of feature richness is their extensive customizability. Indeed, as stated before, the code source is available so that any customization can be undertaken. Moreover, it is a real asset to create task-specific software with only the functionality needed by the end users, especially for non computer-literate end users (Moreno-Sanchez, Anderson, Cruz, & Hayden, 2007) who constitute most users in CBOs. However, it has to be kept in my mind that any customization requires serious IT and programming skills which may not be available in a CBO.

The poor usability of OSS has long been a barrier to their use by average users. Indeed, the usability defined by ease of learning, efficiency of use, and subjective satisfaction (Nielsen, 1993) was hampered by flaws inherent to the open source development. The reasons are thoroughly described by *Nichols & Twidale* (2003). The main ones are the lack of a user centred-design, the lack of human-computer interface expert, and the difficulty to specify usability. However, when an OSS solution reaches a certain level of maturity and success, it widens its base of users so that its usability requirements and efforts to improve the human-computer interface become close to commercial software ones. Therefore, it is preferable for CBOs to consider mature OSGIS solutions only.

Due to their architecture and their lower number of default features, OSGIS have smaller resource footprints than their commercial counterparts (Lowe, 2002, Anderson G. , Moreno-Sanchez, Cruz, & Hayden, 2007). Therefore, their less stringent hardware requirements combined with the drop of the price of the computer material gives an opportunity to CBOs to implement GIS software for nearly no material cost.

A key development that has encouraged OSGIS acceptance and use is the creation and the popularization of open standards by the Open Geospatial Consortium (OGC). The OGC is a consortium of companies, governmental agencies and universities which works on enabling spatial information and systems interoperability. To do so, the OGC has created a set of specifications, called open standards, which consists in programming rules and advice for implementing interfaces and protocol to foster spatial system interoperability. The most widespread OGC open standard is the Web Map Service (WMS) which specify how to implement a service that delivers map images in response to client request. Thus, any client who makes requests according to the standard can get data from any service respecting the standard to publish its data. Therefore, it is extremely powerful to exchange data and National Spatial Data Infrastructure (NSDI) such as the Canadian Geospatial Data Infrastructure (CGDI) in Canada or Infrastructure for Spatial Information (INSPIRE) in Europe relies on the use of open standards. Besides, they are especially important for OSGIS because of the need for several packages to be assembled to capitalize on other developments and to create robust applications. OSGIS fully respect the open standards whereas their implementation in commercial software has been less complete to date. Therefore, the use of OSGIS is an advantage to integrate a new GIS program with the existing GIS infrastructure or with future GIS development or to cooperate with other organisations.

One of the differences between commercial and open source GIS is the type of Support. The commercial hotline is replaced by internet mailing list, archives, and support database. The support is free whereas it often costs extra money with commercial solution. One can argue that the open source support is not as good as a commercial one. However, in practice, the open source support is good and efficient especially for mature and active project (Wheatley, 2004) as it is shown in the case study below. Moreover, for popular projects, there are companies that provide commercial support for OSGIS, for instance the company Refractions Research based in Victoria, Canada or Camptocamp based in Lausanne, Swiss.

Finally, the spirit of openness, cooperation, and contribution of the open source community can facilitate and encourage the own CBO spirit of motivation and cooperation (Anderson G. , Moreno-Sanchez, Cruz, & Hayden, 2007).

b. Advantages and requirements for the use of OSGIS by CBOs

As stated earlier, CBOs have many difficulties taking advantage of GIS technology due to their limited funds, staff and other resources. Indeed, the acquisition of pricy commercial licenses would represent a significant part of their budget and a big commitment, if they could ever afford it. Therefore, the free license of OSGIS is crucial for the start of a project. Although, due to the need for custom programming, the total cost of ownership of an OSGIS may appear to be the same as that of proprietary software. It will be likely considerably lower, especially for CBOs which are small (Holck, Persen, & Larsen, 2005). Indeed, the small footprint of OSGIS and the drop in the price of computer hardware allows CBOs to buy relatively low-end hardware to make them run (Moreno-Sanchez, Anderson, Cruz, & Hayden, 2007). Concerning the support and staff costs, the support is free and a staff of one or few people with basic IT knowledge will be able to get started with OSGIS. However, CBOs must use mature OSGIS solution to avoid troubles such as the lack of documentation and poor usability. Moreover, IT staff has to be highly motivated and be able to make its own way through the documentation to start. Therefore, the IT team must be constituted of at least a local champion or a small core group of motivated people. The IT staff does not need programming experience since most mature OSGIS solutions offers a decent number of out-of-the-box features which are sufficient to meet basic needs as it is shown in the case study below. However, if the CBOs want to customize an application or add advanced or specific features, programming skills are required and the time to develop them can increase significantly the TCO. Beside a motivated IT staff, all the organizational factors mentioned in the last part have to be met so that the IT staff work is not hinder by external factors and even it can be facilitated by accessing local sources of support.

To sum up, CBOs with limited funds and staffs are able to benefit from the GIS technology by using open source GIS solutions even though they have to be aware of the requirements and limitations mentioned above.

IV. Selection of a suitable OSGIS

OSGIS which once emerged from an expert community have today been proven to be a legitimate choice for CBOs with limited resources as the last part shows. However, there is a myriad of OSGIS available across the Internet as the long list present on the websites, the Open Source GIS and the Free GIS database, testifies. Thus, it is challenging and confusing for non-expert users to find their own way through. Therefore, to help CBOs in their choice of an OSGIS, the remainder of this paper will establish basic principles to assess and select OSGIS according to CBO characteristics and needs.

1. Developing a set of criteria:

The selection of a suitable OSGIS begins with the specification of the CBO needs as for selecting any software even non open source. The definition of the needs allows the identification of a set of candidate applications. The framework of the CBO needs elaborated in the first part defines categories of generic needs that match with several categories of software: desktop GIS, web GIS, web 2.0 GIS, customized GIS. Therefore, the framework can be used to define a first set of potential solutions.

Then, these candidates have to be compared between them to determine the most appropriate ones. When dealing with OSGIS, two types of criteria are to be evaluated. The first type consists in the criteria which have to be considered whether it is open source or not, for instance, functional capability, speed of execution (Wang & Wang, 2001). This type of criterion will no be described in this paper. The second type of criterion is the one specific to the open source software, especially the ones which are related to the maturity of an open source project.

Once a subset of robust solutions has been determined, the final step is to perform an in-depth analysis. This analysis account for precise needs that CBOs must specify according to their goals and the context they operate in, for instance, the specific functionalities they necessitate.

The two next parts give some guidelines to perform the open source maturity analysis and to determine the context-specific criteria that have to be taken into account for the in-depth analysis.

a. Open source related criteria

The criteria related to the open source nature of the software are essential to examine since CBOs with limited skills will not be able to use solutions in their early stage of development. Moreover, they need to take advantage of the reliability, performance and support of the mature solutions. Numerous criteria have been provided through the literature to assess the maturity and the robustness of open source software (Wheeler, 2008, Wang & Wang, 2001, Ramsey, 2007). Here are presented the criteria which are of a particular importance to the CBOs and the barriers they face.

First, the dynamism of the software community has to be assessed. To do so, the sizes and activities of the user and developer communities are the best indicators. Concerning the developer community, the vitality of the project can be assessed by browsing through the website and checking diverse characteristics. When was the last update release? What is the frequency of the updates? When was the latest news published? Is the developer mailing list teeming with questions and answers? Was the project presented in conferences such as FOSS4G? Does the project have other contributors than the core team? Does the project have financial sponsors? Is the organization of the project contributors well defined? Is the development transparent, documented by a roadmap and RFCs? Concerning the user community, user mailing lists and forums are also to be examined but a determining element is the records of success that can be examined through website link, press articles, reports posted on the project website. In this case it is relevant to ask the following questions. Who used the software? A use by large governmental organizations or by private companies for a commercial use is generally a proof of robustness. What did they do with it? What is their feedback? The answers to these questions permit the selection of a set of mature OSGIS. The maturity of the solution has a strong influence on its robustness and its quality of support.

The quality of the support is a crucial element for the adoption of an OSGIS by CBOs. Indeed, they generally have limited staff resources and limited skills so that they can rely entirely on the help provided through the community. The primary support is the user manual and tutorials. They have to be complete and make users get started easily otherwise they can hit technical barriers at the very beginning which can discourage them and make them give up. Beside the manuals, an active mailing list or forum is required, especially to answer to unexpected issues. The upmost support can be a commercial support offered by a company. However, CBOs have generally not enough funds to take advantage of it. In the case of a software customization or an adding of features, the completeness of the developer documentation has also to be checked. The developer documentation can contain a developer manual, tutorials, a software design documentation and Application Programming Interface (API) documentation.

The OSGeo website[10] is worthwhile to browse when looking for mature OSGIS. Indeed, the OSGeo implement a process of incubation that ensures a certain level of maturity before the OSGIS project can join the foundation. As such, it gives potential users of an OSGeo project added confidence in its viability and safety.

[10] Available at http://www.osgeo.org/home

b. Context-specific criteria

Once a set of mature OSGIS have been selected, CBOs have to perform a more detailed analysis accounting for their specific needs. First, they have to check if the candidate solutions possess out-of-the-box feature that meet their specific needs. Indeed, it is a significant advantage since it prevents them from doing any programming. Therefore, this enables them to use the software with non expert staff and no or less training which lowers the software exploitation cost.

However, OSGIS generally present a limited number of out-of-the-box features so that CBOs may have to use different applications to meet all their needs which can increase the complexity of the use or even, in the extreme case, they may have to program the function they require. Besides, CBOs may whish to undertake a customization or feature adding. In these cases, CBOs have to consider some other aspects. First, the undertaking can be done in-house or by paying someone like a consulting company. However, CBOs can rarely afford to pay to contract out the development so that they have to rely on their own resources. Therefore, they must check if the application they want to customize is written in a programming language that matches the staff skills. If not, they may prefer to switch for project that is developed in a technology mastered by the technical staff. If a project or several projects match the staff skills, a more thorough examination have to be performed to assess the level of complexity required to complete the customization. Indeed, it implies time and money spent. The software has to be modular and clear methods to add functionalities have to be provided. Therefore, the completeness of the developer documentation mentioned above take all its importance since it gives key elements to evaluate the time required to complete the customization. The last step is to dive directly into the source code.

The second important point to consider is the interoperability criteria. Can the potential candidate read/write the data type we possess? Is it fully OGC compliant? Can it read some proprietary formats? OSGIS thanks to their implementation of the OGC open standards should be able to read/write any data implementing them but sometimes data can come in a proprietary format that not all OSGIS can read. The two last points are the integration with the existing software and hardware infrastructure. Can it be easily integrated with existing software or old software? Is the existing hardware sufficient to run it?

Project name	Non OS Criteria	OS Criteria											
		Vitality							Quality of support				
		Developer community				User community			User			Developer	
	Feature richness, Speed…	Latest Versions and News	Others contributors/Sponsors	Size/Activity of the management mailing lists	Transparency of the management	Size/Activity of the user mailing list	Record of success	Presence in the GIS world: conference, press articles	Manual, tutorials	Mailing list, forums	Commercial Support	Manual, design documentation	Mailing list

Project name	Context-specific criteria					
	Customization, Adding functionalities			Interoperability		
	Modularity, design of the program	Development environment		Data		Software
	Ease of adding new functions	Languages	IDE	OGC	Proprietary format	Language, data format

Figure 3: Sum up of the criteria

2. Examples of potential solutions

This last part looks to demonstrate the ideas exposed in this paper. It consists in applying the principles enounced above to select and evaluate potential OSGIS solutions and to emphasize the advantages of using OSGIS for CBOs, exposed in the third part of this paper. The studied applications are a sample arbitrary chosen amongst the most popular projects. The selection and assessment of a piece of software begins with the definition of the needs. The needs defined in the framework of the first part are used here as generic needs to structure the selection process.

a. Desktop GIS

The first CBO need defined in the framework is the management and processing of spatial data. This need can be described in a simple test scenario for the evaluation. CBOs want to be able to easily install the application, to quickly get started, to open and format the data, to perform processing on these data and eventually to print maps. We saw that the functionalities required to meet these needs lead to the use of a desktop GIS. Therefore, two of them have been picked up: gvSIG and Quantum GIS (QGIS). They both pertain to the OSGeo. QGIS has graduated the incubation process and gvSIG is under incubation. Therefore, they should show evidences of maturity.

- **gvSIG[11]:**

The gvSIG project was started at the end of 2003 by the Regional Council for Infrastructures and Transportation (Conselleria de Infraestructuras y Transporte, CIT) of the Valencia province (Generalitat Valenciana) which put out to public tender the development and implementation of a new software application for the management of geographic information. Today, the CIT is still the promoter of the project with the collaboration of the Universidad Jaume I, member of the TeIDE, consortium, to coordinate and monitor that the development follows all the international standards (Open GIS Consortium) and IVER Tecnologías de la Información, the consulting company awarded with the tender, which is responsible for the development. Even though the development is supervised by a consulting company, the project is entirely open source and applies the open source concepts described in part III. Besides, having a consulting company participating in the project is an advantage since they can offer commercial support and consultancy. The vitality of the project is good since the latest news is dated from March 27th 2008, the latest version from March 4th 2008. The frequency of minor updates is about 3 months. Moreover, gvSIG has established is own annual user conference, gvSIG conference, since 2005 and numerous articles and reports available on the website show the presence of gvSIG at different GIS

[11] Available at http://www.gvsig.gva.es/, accessed on June 20th, tested version: 1.1

events such as FOSS4G. Therefore, it appears that gvSIG has a dynamic developer and user community and constitutes a mature, promising desktop GIS which deserves to be tested more in details.

The in-depth analysis is performed by assessing gvSIG capabilities through the scenario elaborated above. First, the binaries of the last stable version for Windows, Linux and OSX are easily and quickly downloaded from the project website. Only the Windows installation is performed in this paper. It is a simple click and go installation where all the required files/packages are bundled in one file. No quest for obscure packages across the internet and no manual modification of files are required. Therefore, the installation phase can be conducted by anyone who has very basic computer skills and should not give CBOs any concern. The familiarisation with the software is ease by a user-friendly interface and a user guide of 409 pages which enable anyone, previously familiar or not with GIS, to use the software. There are even tutorials and courses on DVD available for free. However, they are not translated in English yet. It shows that often in open source project less effort are put into translation which is really time consuming task and requires specific skills not always available.

The data formats supported by the software are an essential point to examine since CBOs can have data from various sources in various formats. gvSIG provides a quick access to the most usual raster, vector, spatial database formats including open format such as gml, geotiff and some proprietary including dwg, dxf and oracle spatial. Some of them are supported in writing mode. The full description is provided on their website. Moreover, gvSIG is OGC compliant so that it can be a client for any OGC services including WMS, WCS, and WFS. Indeed, it is even the reference software used to test the implementation of the European SDI, Inspire. Therefore, it allows CBOs to integrate many different data sources together.

Once CBOs has been able to quickly get started with software and to load their data, they may want to perform some editing, processing and analyses on the data. To do so, gvSIG provides classic editing features to add and modify entities and a decent number of built-in vector analysis tools including buffering, various overlaying and also scripting capabilities. Moreover, these features are completed by advanced capabilities provided by various extensions which can be installed as easily as the main software. Some of them provide capabilities to interoperate with commercial software such as ArcIMS, ArcSDE, and Oracle Spatial. Some of them provide advanced analysis raster and vector functions such as the Sextante extension which enables the use of 210 processing including geo-statistics, vegetation indexes, network, profiles and hydrological analysis. Moreover, the gvSIG project has recently developed a mobile version of gvSIG called gvMobile which prove that the project is on the leading edge of the GIS world.

Eventually, CBOs want to publish their data and analysis results in a paper map form or even in a web form but this leads to next part. To publish paper maps, gvSIG provide capabilities to format a map dynamically linked to the GIS view and to insert automatically generated legend, scale and north arrow which are the main functions required to format paper maps.

- **QGIS[12]:**

QGIS is a solution who graduated the OSGEO incubation process. Therefore, it can be stated that QGIS is a mature solution. A peek at their website can confirm it by the presence of elements such as the description of the organization of the project team, its different mailing lists and the companies' commercial support, to cite just few. The QGIS interface is more recent and user-friendly than gvSIG one. QGIS has all the basic features of a desktop GIS system including opening, formatting and editing data, and printing of maps. However, QGIS is not able yet to read as many data formats as gvSIG especially concerning database and proprietary formats. Moreover, it has significantly less out-of-the-box geoprocessing features. One remedy is to use the GRASS extension that link QGIS to GRASS but it is not as practical as integrated geoprocessing functions. Besides, two features unique to QGIS are to be mentioned. Its GPS tools enable quick manipulation and display of GPS formats. The possibility to export the map formatting for MapServer as it is mentioned below.

To conclude, the review of these two examples shows that OSGIS can provide desktop GIS with capabilities that meet the generic need of data management encountered by CBOs. Moreover, these mature solutions lower the barriers exposed above. Indeed, they are free and they can be installed and used by people with limited IT skills thanks to a good support.

b. Web GIS

The second CBO generic need defined by the framework is the publication of spatial data on the web. This need can be broken down in a scenario for the test. First, CBOs need to put up a web server to host their website, to format and publish their data through a website or a web service, and to eventually customize or develop websites. We saw that this need leads to the use of a web GIS which consists in two independent components: a map server and web server. The web server is a generic web

[12] Available at http://www.qgis.org/, accessed on June 20th, tested version: 0.9

server that hosts a website but that has no map display capabilities. The map displaying part is done by the map server. Except in the installation part, the focus is made on the map server and its capabilities.

- **MapGuide Open Source[13]:**

Autodesk MapGuide was an application developed by Autodesk since 1996. Although progressing through successive versions and meeting success for its ease of use, the software happened to have strong technical limitations especially because all the spatial analyses were client-side performed and the platform was windows centric. Therefore, the project was turned into an open source project called MapGuide Open Source (MapGuide OS) and a group of developer works on retaining the best aspect of the old MapGuide, and on restructuring and reprogramming the whole application by using open source libraries. The company Autodesk still develops commercial software with extra features around the open source project but the project is fully open source and applies the open source concepts described in part III. Moreover, the consulting company DM Solutions participates in the development and provides support and consultancy on MapGuide OS. The project structure is well defined with different level of responsibilities, Project Steering Committee (PSC), Project Developers, Project Contributors and the positions are attributed on merit and internal votes. A roadmap and RFCs are available on the developer website. Therefore, MapGuide OS has a well structured and transparent management. The latest news is dated from March 21st 2008, the latest version from May 21st 2008 and the frequency of minor updates is about 4 months so that the project can be considered as active. The website provides demonstration and screenshot of the different capabilities of the software. However, one has to be suspicious about these proofs of success. Indeed, often some software work perfectly with demonstration data and application but they may become a nightmare as soon as one tries to use them on their own. Besides, the records of success provided by their website are limited since there is only one reference to a real use of the software and no presence at a conference or press article. There may be some which are not mentioned on the website nevertheless it sparks some doubts on the acceptance of the project by a wide user community.

The other criteria such as the level of support, the context-specific criteria are studied through the scenario elaborated above. First, two installers are provided on the website: one for the mapping engine part, MapGuide Server and one for the web engine part, MapGuide Web Server Extension. Therefore, one has the option to install just the mapping part and use its own web server or to use the version provided by the website and thus to benefit from the fact that everything is installed and configured automatically. Hence, CBOs with limited skills can install and configure both parts just by using user-

[13] Available at http://mapguide.osgeo.org/, accessed on June 20th, tested version: 2.0.1

friendly interface. Once the server is running, a getting started documentation allows the new user to easily publish a data sample already packaged. However, this is the only user documentation and no other elements are provided. The user has to find his own way to format and publish his own data by guessing and reading few posts in forums. Even though it is eventually not hard, it can discourage more than one regular user. The formatting of the data to be published is done by using a Graphical User Interface (GUI). There are three different GUIs available to perform this step: MapGuide Open Source Web Studio, a web interface provided with the installation, Autodesk MapGuide Studio, a proprietary desktop application developed by Autodesk but which can be obtained in a 60 day trial version and MapGuide Maestro, an open source version of Autodesk MapGuide Studio. The web version and the open source desktop version appeared to be quirky, unstable due to a lack of maturity so that the user has to resort to the commercial software. This is an annoying fact since we aim at reducing the cost for CBOs with stringent financial constraints. The publishing of the formatted geographic data is also done thanks to one of the GUIs. It allows the user to use website templates so that no web programming is required to put online a website. The proposed templates are even customizable so that the toolbars and menus can be modified through the GUI.

On the overall, once some hurdles such as the lack of user documentation and the lack of maturity of the open source GUIs are overcome, MapGuide Open Source can allow CBOs to publish a mapping website with the data formatted as they want without having to do any programming but just by using user-friendly interface. Therefore, there is no licensing cost and no expertise required which is a great advantage for a use by CBOs. Hopefully, the two open source GUIs will soon be more robust so that CBO can format and deploy a web GIS by using only GUIs which are open source.

Concerning the addition of features and the customization of the software, the developer resources are quite important with a developer's guide and the API documentation. However, there is not much reference on the successful implementation of MapGuide OS-based website so that it may hard to find some help in case of problem because of a limited user community.

- **MapServer[14]:**

MapServer is the most popular and successful OSGIS. It has hundreds of records of success with their links available on the website including the Atlas of Canada and the United Nation Environment Programme GEO Data Portal. Therefore, we do not go through the open source maturity criteria but one can easily convince himself by scanning through the website. Thanks to its wide user and developer

[14] Available at http://mapserver.gis.umn.edu/, accessed on June 20th, tested version: 5.0.2

communities MapServer is a very robust solution and possesses a good support through its abundant documentation, very active mailing lists and even books (Kropla, 2005). MapServer also provides a bundled installation with the mapping and web server. However, it is more complicated to use than MapGuide Open Source. Indeed, the formatting of the data has to be made through the modification of a text-based file and there is no website template provided with MapServer so that the development of a web interface is required. However, some solutions start to appear to provide user-friendly tools. QGIS offers the possibility to export the map formatting into the MapServer format therefore the map formatting can be done by using a user-interface. However, the tool is not entirely stable yet. Besides, some extensions built on top of MapServer such as Cartoweb[15], Chameleon[16] provides tools to quickly develop a website for MapServer. All these tools are promising and make MapServer more user-friendly but most of them still require important computer skills to be used. Thus, if the CBO staff has no IT and programming skills, it can be tedious to use. With IT skills, the staff should be able to get nice results even though it requires some time.

To sum up, MapGuide OS and MapServer give CBOs the opportunity of publishing a geospatial website. Indeed, they are both free to use and they can offer various levels of use difficulty. A CBO with limited skills which wants to put together a web GIS can do it without any programming, just by using GUIs with MapGuide OS. However, it has a limited user community. Therefore, advanced uses can be hindered by the limited support. On the other hand, MapServer can be tedious to use just to publish a basic website. However, it has a wide user community so that it offers a more robust solution with a better support. This can be determining for CBOs with relative IT skills which want to undertake advanced uses and customizations.

c. Web 2.0 GIS

As seen in the first part, Web 2.0 GIS allow CBOs to gather information from the public. This broad need can be turned into different Web 2.0 GIS according to the different CBO goals. Therefore, no generic scenario and detailed review can be elaborated to embrace all the possible different Web 2.0 GIS. A CBO willing to develop a Web 2.0 has first to well precise its needs and then to perform the process presented above to select the appropriate technology. However, some guidelines can be given since Web 2.0 GIS are based on one type of technology: a regular mapping website on top of which are plugged modules to allow interactions with the users. Therefore, APIs provided with the main Web GIS

[15] Available at http://www.cartoweb.org/, accessed on June 20th

[16] Available at http://chameleon.maptools.org/index.phtml?page=home.html , accessed on June 20th

solution are likely to be used, for instance, the MapServer API and its extensions such as CartoWeb or the MapGuide OS API. They are available in different languages: PHP, .NET, Java. It is worth mentioning the free of cost but non open source Google Map API. Indeed, it can enable a quick development of a Web 2.0 GIS. However, it is considerably less flexible than the two previous solutions since the application looks like Google maps and Google has the right to add ads with a 90 day notice.

Obviously, this kind of undertaking requires strong programming skills. Hence, CBOs who want to develop this type of tools have to ensure that they have enough funding and skills to realize it.

d. SDSS

The development of an SDSS is entirely related to the context and the goals of the CBO. Therefore, there is infinite number of different needs so that it is not possible to explore all of them. The CBOs willing to pursue this kind of undertaking have to perform a detailed analysis based on a precise need definition. The CBOs with relatively small staff resources have likely to look for help from a consulting company or a university.

V. Conclusion:

CBOs have often to deal with spatial problems due to their local nature which implies spatial interactions. Therefore, their efficiency in communication, public input, issue solving and decision making can be significantly enhanced by the use of GIS. However, they have limited financial and staff resources that prevent them from using commercial GIS software. Today, it appears that OSGIS can constitute a good substitute to commercial GIS for a zero license cost. Indeed, the most mature OSGIS have reached very good level of usability and support that allows non-GIS literate staff to use them. However, OSGIS are still slightly behind commercial GIS especially in the number of out-of-the-box features and the amount of documentation so that the selection of a suitable solution requires care and their use may require a strong motivation. Nevertheless, OSGIS are quickly catching up commercial software for a non-expert use as their user community is growing. Indeed, the more users a project has, the more it is tested and the more contributions there are. Therefore, the most advanced OSGIS are close to pass the tipping point that will make them usable for CBOs with less requirements and precautions. To date, an OSGIS selected with care is a real opportunity for CBOs to take advantage of GIS technologies.

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