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GIS for All: Exploring the Barriers and Opportunities for Underexploited GIS Applications

Hao Ye
Nottingham Geospatial Institute, University of Nottingham

Michael Brown
Horizon Digital Economy Institute, University of Nottingham

Jenny Harding
Ordnance Survey Southampton

GIS for All: Exploring the Barriers and Opportunities for Underexploited GIS Applications

by Hao Ye[1], Michael Brown[2], and Jenny Harding[3]

1: Nottingham Geospatial Institute, University of Nottingham; 2: Horizon Digital Economy Institute, University of Nottingham; 3: Ordnance Survey Southampton. isxhy@hotmail.com

Abstract

Geographical Information Systems have been existed since the early 1960s, but evidence suggests that adoption of GIS technologies still remains relatively low in many sectors. We will explore both the barriers that affect the utilisation of GIS and opportunities to overcome these barriers. As part of this exploration we performed a literature review, collected responses from quantitative questionnaire survey and interviewed a range of technical and domain experts. Having analysed and collated the results of these studies we have identified ways forward for future research and development to facilitate wider spread adoption and exploitation of GIS applications. Our discussion focuses on the importance of open-source GIS software, open data and cloud computing as key mediators for breaking the barriers and promoting the wider appropriation of GIS based solutions.

Keywords: GIS barriers, GIS opportunities, Open-Source GIS, Open Data, OpenStreetMap, Cloud Computing.

1. Introduction

The development of Geographical Information Systems (GIS) began in the early 1960s and rapidly advanced since the late 1980s. Over the past 50 years, GIS technology has been increasingly introduced to a wide range of sectors. In addition to planning agencies and local governments, many other sectors have been involved, such as social science, transportation, earth science, military, agriculture, environmental protection, etc. The integration of GIS technology in traditional geospatial tasks provides a number of optimal solutions for individuals/groups, e.g. policy developers, decision-makers, managers, researchers, and allows the performance of existing tasks cheaper, faster and more completely (Elangovan 2006).

The multidisciplinary nature of GIS technology means that the diffusion, appropriation and use of GIS technologies are distributed in a variety of subject domains, was and is often regarded as a new technology or approach on traditional task with specific disciplines. This characteristic means that the adoption of GIS technologies have not yet fully delivered its potential or adequately addressed the need of GIS users in many domains (Ventura 1995, Nedovic-Budic 1999). Early studies have mentioned that most users adopt GIS technology in relatively simple applications but rarely use it for sophisticated tasks (Nedovic-Budic 1998). More specifically, these studies indicated that the expectation of GIS technology in the areas of geospatial analysis and decision-making was particularly high but the penetration is relatively low. The task demands were either not achieved at all or not achieved as expected due to barriers and factors that hinder the utilisation of GIS.

Some researchers have investigated the direct or indirect barriers which affect the adoption rate of GIS from early stages (Ventura 1995, Nedovic-Budic 1999, Esnard 2007, Akingbade et al. 2009). This previous work has identified the existing barriers found for effective use of GIS and classified them into two board groups(Brown 1996, Brown & Brudney 1998, Esnard 2007, Yap et al. 2008, Asligui Gocmen & Venturac 2012) ;

- **Organisational barriers**: generally referred to department factors, such as lack of staff (e.g. constraints by size of the team or funding), lack of purpose or mission to promote GIS application and lack of collaborators and networking.
- **Technical barriers:** including lack of context, insufficient software and tools, lack of reliable data and lack of technical knowledge.

In addition, another difficulty is the fast paced updating and development of GIS technology. Empirical knowledge is still scarce on the changing barriers accompanied with rapid advances of GIS technology, as well as potential solutions to justify the possibility for problem-solving.

The aim of this paper is to gather information from the literature, as well as questionnaire re-

sponses and expert opinions to identify and update the GIS barriers. In addition we aim to explore the potential opportunities, in terms of Open-Source GIS, Open-Data and Cloud Computing in overcoming these barriers. The current application domains of GIS and existing barriers were re-examined as it is important as focal points for the identification of future opportunity and proposal of potential solutions. This study intends to explore the following research questions:

1. Who are the current users of GIS and what is the current state of GIS applications?
2. What current opportunities exist for exploitation of GIS beyond commonly accepted applications?
3. What are the existing barriers that result in the underutilisation of GIS?
4. What possible solutions exist for overcoming the barriers and realising the opportunities that have been identified?

This study provides a brief overview of the inroads made by GIS, highlight a way forward for GIS researchers, professionals and developers to fulfil potential users' unmet needs and promote everchanging practical development. The rest of this paper is divided into 4 sections. Section 2 gives an overview and analysis of literatures exploring the current application and barriers of GIS in several selected domains. Next, Section 3 describes the results of a questionnaire survey and interviews with GIS users and experts exploring this area. Section 4 discusses the potentials of recent technologies toward breaking the barriers. Finally section 5 provides general conclusions.

2. Literature Survey: Applications and Identified Barriers

In order to have an impression of the current state of GIS applications, as well as an update of the impediments for GIS adoption, literature was searched and revisited, and analysis was conducted for application and barriers identified in past studies. In this paper the literature review focused on 4 well-known fields of GIS application, including *Government, Transportation, Commercial Sectors, Public and Educations*. The selection might not contain comprehensive application domains, but it draws an impression about the trends of the mainstream GIS applications. The literature search for relevant publications was performed by using web-based search engine. The search was carried out based on a Boolean search containing the keywords such as "GIS barriers", or "GIS" and relevant 'application field' selected above. The searched articles and referenced articles containing the terms were selected and reviewed. The GIS application domains and identified barriers were analysed and summarised.

Government

The government sector was an early adopter of GIS, and has been a major user over the last 20 years. GIS has been utilised in major governmental sectors such as land management, coastal condition monitoring, census statistics, disaster management, environment protection, military, administrative purposes, surveying, etc (Brown & Brudney 1998, Longley et al. 1999, Montoya 2003, Fleming et al. 2009, Sunarto 2011, Gregory 2012, Mendas & Delali 2012).

The review revealed that when GIS emerged as a valuable technology in the 1990s, a number of researchers started to examine the barriers of GIS implementation in local governments (Brown 1996, Nedovic-Budic & Godschalk 1996, Brown & Brudney 1998,). These studies primarily identified three types of main barriers for government staffs, including: (1) lack of programs/software for desired application; (2) lack of awareness of available tools; (3) lack of national initiatives. In recent years, some extensive studies have been conducted to reveal that, except for former barriers, some updated barriers for GIS users. For example, current GIS users cannot catch up with the technology advancements. One typical example is the adoption of emerging internet-based GIS in urban planning and decision-making (Peng 2001, Drummond & French, 2008). Some other studies suggest that the barriers of GIS adoption in planning sectors are similar to the impediment of adoption of GIS in other governmental sectors (Greetman & Stillwell, 2004).

Transportation

Transportation has always been one of the most important domains of GIS application. To date, GIS has been applied to different transport problems, such as short path analysis, vehicle routing, trip investigation, road navigation, dynamic routing, accident analysis, Intelligent Transport System (ITS) (Aultman 1998, Xu 2005, Pons & Perez 2003, Kim et al

2011, Deshpande et al 2011).

Past studies have revealed that transport modellers are used to coding up abstract road networks and managing transportation data non-spatially. Many transportation planners are unfamiliar with GIS data management and tools. Therefore, at that time the barriers to GIS utilization are likely to be technical, referred to as lack of awareness. Other barriers identified included insufficient tools and data required by many transportation applications (Sutton 1996). Researcher in highway sectors summarised the barriers for implementing GIS application include: (1) unaware the benefits of GIS; (2) lack of good communication between highway engineers and GIS engineers; (3) standards for data consistency; (4) insufficient data; (5) lack of knowledge in understanding GIS methods (Smith 2012).

Commercial Sectors

Since GIS contains of many powerful software toolsets for the integration of commercial data and geographical information, it enables a wide range of opportunities for different business domains, such as banking, insurance, logistics, media, real estate and retail (Jafrullah 2003). A detailed summary has been provided by about the application of GIS in commercial sectors, as well as the techniques that could be adopted for the applications by Dangermond (2001). The primary use of GIS in commercial sectors is to analyse the distribution of customers in order to expand customer base, improving service quality and consistent business profitability. In fact, the "Geomarketing" is a term dedicated to describe the commercial GIS, which include the studies of consumer's spatial behaviours, marketing and consumer's values, lifestyle and geographical information as well as the location of retail for market demand and service activities (ESRI 2003, Gerard 2006).

The past studies shown that the main barriers of GIS in social sectors (including commercial sectors and non-profit sectors) are the cost of GIS and lack of internal expertise. Finance resources were insufficient to support in-house GIS at market value and outsourcing costs exceeding $100 per hour are not easily justified for small and medium organisations. It also mentioned that the increase of GIS application practices is important for the consideration of potential selection of GIS in various sectors (Edwards, 2011).

Public & Education

GIS have attracted wide interests for public and education sectors in the past 30 years, e.g. measuring libraries accessibility, aquariums, building attack simulation, high schools and university education (Wheeler et al. 2010, Park 2012, Kevany 2003, Singh et al., 2012).

The research of integrating GIS as tools into school curriculums have been conducted for a deeper-learning experience and participation. However, three main challenges were identified as: (1) hardware issue (i.e. powerful computing to store and interpret data); (2) software and data (i.e. free is important for school); (3) teaching skills and competence (Wheeler, et al. 2010). A study conducted by Read et al. (2005) has highlighted the benefits and potentials of adopting GIS for educational marketing, but a few significant barriers referred to general implementation were also addressed, such as: (1) lack of data and skill exchange and cooperation between department; (2) lack of user-friendly software interface for novice users; (3) acceptance of new tools and methods for traditional tasks; (4) expensive geo-demographic data; (5) licence permission for GIS software. This study particularly draw attention to insufficient GIS data sources, especially these high-quality and well-documented data.

Table 1: The review summary of GIS application domain and the identified barriers.

Domain	Application areas	Identified barriers
Government	▪ *land management* ▪ *coastal monitoring* ▪ *environment protection* ▪ *census statistics* ▪ *fire management* ▪ *military* ▪ *administration* ▪ *surveying*	▪ *insufficient programs* ▪ *lack of awareness of tools* ▪ *lack of initiatives/mandates* ▪ *lack of support from managers* ▪ *understanding technology*
Transportation	▪ *short path analysis* ▪ *vehicle routing* ▪ *trip investigation* ▪ *road navigation* ▪ *dynamic routing* ▪ *accident analysis*	▪ *insufficient tools* ▪ *lack of expertise* ▪ *lack of professional staffs* ▪ *training* ▪ *understanding technology* ▪ *lack of communication*
Commercial Sectors	▪ *banking* ▪ *insurance* ▪ *logistics* ▪ *media* ▪ *real estate* ▪ *retail*	▪ *expensive cost* ▪ *lack of expertise* ▪ *lack of data*
Public & Education	▪ *libraries* ▪ *museums* ▪ *nature centres* ▪ *high schools* ▪ *Universities*	▪ *lack of cooperation* ▪ *insufficient software and data resources* ▪ *lack of proficient teachers* ▪ *acceptance of new technology*

The survey in this section has conducted a condensed review of literatures about the GIS application domains, as well as the barriers for improving GIS adoption rate. It is clear, from the summary in Table 1, that the applications domains of GIS vary,

but barriers in different sectors are not incompatible. If dividing the barriers into organisational and technical factors described above, the government suffer more from organisational factors such as understanding technology, lack of awareness, and lack of organisational support. The Transportation sectors are restricted by some technical factors such as lack of tools and expertise. The commercial sectors expect cheaper and better software, and more reliable and convenient data. Public and Education sectors expects more cooperative and experts. These barriers show different underutilisation and potential expectation from GIS technology.

3. Questionnaire Survey for Barriers of GIS Use

A questionnaire survey was designed to identify the entry barriers from current GIS users and underutilised opportunities from their respective backgrounds. Questionnaires were sent to 30 candidates to inform the survey and the authors collected 22 valid questionnaires from them. These questionnaire participants were mainly selected from two organisations: the school of Civil Engineering at the University of Nottingham (10 candidates, all of them are PhD students, various engineering backgrounds) and Ordnance Survey in Southampton (12 candidates, 8 staffs in research team and 4 intern students, all of them have geo-science backgrounds), see Table 2 for the statistical summary. Before the survey, the authors investigated the candidates' backgrounds and their relevance to GIS. The criterion for screening was that participants needed to have basic knowledge of GIS knowledge, and at least some experience using GIS software.

Table 2: The summary of participants' backgrounds.

Organisation	Percentage	Backgrounds	Percentage
University of Nottingham	46%	*Geospatial Engineering.*	28%
		Transport Engineering.	9%
		Civil Engineering.	9%
Ordnance Survey	56%	*Geoscience*	56%

The survey questionnaires were designed into two sections: the first section asked relevant personal details, e.g. major in university, current departments; the other section includes some multiple-choice questions and open questions, both referred to the investigations to GIS barriers and potentials. All participants were asked to complete questionnaire and taken part in an in-depth interview exploring their responses to open questions.

Quantitative Results

In order to understand the range of expertise represented, we asked participants to report their proficiency with GIS from one to three: 1) Beginner: just know general principles or ideas of GIS and how to use basic GIS functionalities; 2) Trained User: trained formally by GIS degree, GIS course and workshops; 3) Expert: used GIS up to 5 years or more. The results in Figure 1 show that as is to be expected all participants reported some knowledge of GIS, but otherwise there was a relatively even spread of expertise.

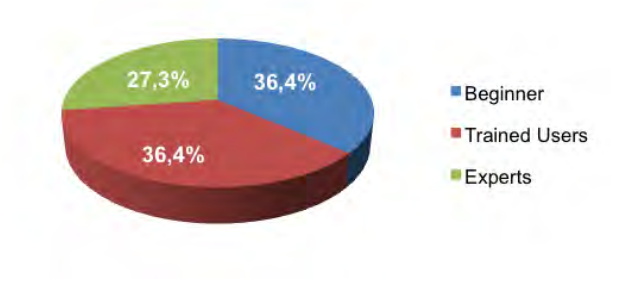

Figure 1: self reported particitipant GIS expertise.

In order to ascertain initial thoughts about barriers to entry, participants were asked to select the three most important barriers that they have encountered from a list of seven identified during the literature review. The results of the response were shown in Figure 2.

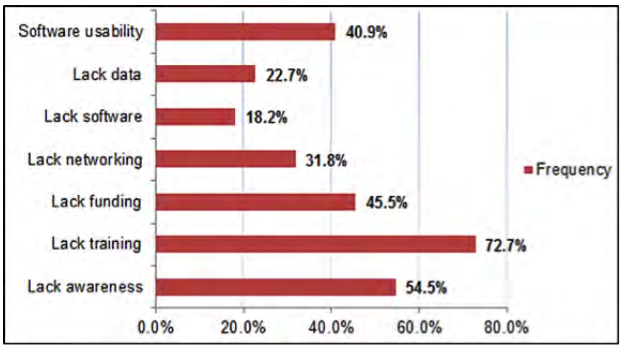

Figure 2: Barriers to entry for GIS .

From the results shown in Figure 2, the most selected factors from participants were *lack of GIS traning* (72.7%), *lack of GIS awareness* (54.5%) and *lack of funding* (45.5%). The three factors can all be seen as organisational factors rather than technical constraints. The development of cheaper, easier to learn GIS could help resolve both lack of GIS lack of funding and training. Surprisingly, the results revealed that many users selected software usability as a sig-

nificant barrier, rather than lack of data and lack of software. This is an interesting finding as many participants are novice users. This effect may be due to the fact that the first impression of GIS for new users is related to interface or operation menus, which affects their impressions of GIS as a tool.

Figure 3: The benefits of GIS technology for users.

The final quantitative aspect of the questionnaire asked particiants to identify the key benefits of using GIS in their work. Four main uses of GIS identifid during the literature reviewwere listed and users were allowed to tick multiple options. The results show that the map presentation, is rated highest (77.3%). In addition, an interesting finding is that the use of GIS for decision-support and planning was only 22.7%. Decision-support and planning using GIS are regarded as promising applications by some but these are apparently still seen as a secondary or future functions by many users. This might be the reason because the participatants are more engineers and researchers rather than decision makers.

Barriers of GIS Use Identified

In-depth semi-structured interviews were performed with domain experts. These experts were selected as they are in close contact with a multiplicity of GIS users from all fields having therefore an extensive knowledge about the problems and needs of GIS users. In this research a total of 6 groups were selected for this interview, including 3 team leaders in Ordnance Survey (i.e. Customer Service, Post-Sales Support, and User Need Research Team) and a technical researcher in Chinese State Bureau of Surveying and Mapping and a renowned academic researcher at University of Nottingham.

Ordnance Survey Customer Service This group noted a range of barriers to GIS use from customer reports as customer service is the main department contacting users, including: (1) methods for data acquisition; (2) data formats and attributes; (3) data manipulation (e.g. download, open, transformation); (4) suitable software for processing data; (5) data specifications modification; (6) data update and maintenance; (7) data quality and reliability. In balance, Customers always hope everything is already there without processing or transformation of anything by them. The participants noted that the majority of customers contacting them use only basic GIS applications. These applications mainly include commercial mapping, web-fit mapping and personal map tracking. They also noted that in many cases people contacting customer service were not using or needing to use the more detailed geographic data or sophisticated software, highlighting demand for easy-to-use and low-cost GIS toolsets free of obstructive technical jargon. Novice users prefer a box of toolkits and data included and easy-to-use, but expert users have higher level demands for map data because they want to modify and update by themselves.

Ordnance Survey Post-Sales Support The Post-Sales team supports Customer Service staffs in resolving specific technical issues, i.e. those relating to software, data or coding. One participant mentioned that the majority of their customers are new users of GIS and that they come from two main sectors: *Commercial* and *Government*. Currently, the main tasks from commercial sector are focused on tracking their commercial assets e.g. water pipelines, insurance properties and transport objects. They estimate that around 50% of the customers are commercial users. The participant revealed that large companies often have their own GIS teams, but most commercial companies lack even a small team. Enquires from the government sector are often associated with the interpretation of new data products. The majority of needs for support concern solving GIS manipulation problems, such as data format transformation. The application of GIS in government sectors varies, but participants found the majority are interested in analysis and routing purposes. For example, using ITN (Integrated Transport Network, a type of Ordnance Survey mapping product) in mapping and analysing footpath networks, efficient fuel consumption and addressing encoding. Some government departments have dedicated GIS teams. These may use GIS for relatively advanced applications such as air pollution assessment. Other government departments might use IT professional or technician to perform GIS analysis.

Ordnance Survey User Needs Researchers Understanding customer's unmet needs is important for developing geographic information products. Through research barriers have been found to vary with the level of expertise of the users. For example, it is maybe relatively difficult for novice users to transform data sets to required formats or understand the attributes within the data. However, for users needing to carry out advanced data analysis, in depth understanding of data specifications, data restructuring and attribute reclassification may be required. Professional knowledge and training can be an issue even at this high level of expertise. Another barrier to use can be insufficient computation power for large GIS data sets. Users who require massive data volumes for national coverage may suffer from low-speed computation in their systems. Modern developments in advanced data acquisition techniques (e.g. sensor data) increases the spatial and temporal density of data collected and is likely to further accentuate this problem.

Technical Researcher This participant shared the opinion that existing GIS software is too complicated for non-expert GIS users. While many GIS companies have made much effort in this direction, they feel that the results to date are not satisfactory. Many simple data viewers and data enquiry tools provide simple functions, such as ArcView, Arc Explorer, but they feel that there is a need for novice friendly GIS software that incorporates more sophisticated GIS functionality. This group suggested two possible solutions to overcome this issue: (1) Develop domain specific GIS solutions for professional users that allow users to complete a limited number of advanced GIS operations; (2) Use data middleware, i.e. an abstraction layer that hides detail about hardware devices or other software from an application in order to provide users with a seamless and simplified interaction.

Geospatial Academic Researcher This research group highlighted the need for GIS experts to make systems that are more closely aligned with user's ways of thinking. According to their comments, "the largest challenge for GIS users is GIS terminology which is regarded as too sophisticated, too technical for user". They have found that with applications such as Google Maps and Google Earth, Google addressed this problem more completely than most expert GIS systems aiming at non-expert users, leading to a move towards web services over dedicated local software, for novice users. In addition to terminology as a barrier, they note that data acquisition should not be ignored given the current cost involved in accruing some data sets. Open Street Map is expected to play an important role for GIS users and developers in future". The participants emphases that training is critical to solve many barriers of GIS, such as lack of awareness and software usability". In response to potential opportunities of GIS, this group identified a wide range of possibilities including In-car applications, real-estate, and simulation. They highlight the integration of GIS and social media (e.g. Facebook, Twitter) to analyse human' behaviours in daily life as an area with huge potential, although it does raise issues such as privacy, security and data ownership. They also mentioned the importance of earth observation including measurements and monitoring of the earth, under water, land surface, air and water quality, atmospheric condition and measures of the health of human, plants and animals.

Identified GIS Barriers Summary

Table 3: The identified barriers from GIS users and expectation for future GIS development.

	identified barriers from participants	expectations on future GIS
Questionnaire Survey	• *lack of fundamental training of GIS (novice users)* • *lack of user-friendly GIS* • *lack of GIS training and meet demands for different level of users* • *lack of knowledge for data processing* • *lack of all-in-one GIS toolbox* • *terminology is to sophisticated and document is too technical* • *lack of integration of GIS with various backgrounds*	• *Develop more training (e.g. workshops, e-learning and online resources)* • *Develop assemble from different teams* • *Develop implementation of ideas* • *Develop user-friendly GIS software and documents*
Expert Knowledge Survey	• *lack of readily available data sources (need transformation)* • *lack of professional teams in many sectors* • *concern data quality, maintenance and reliability* • *lack of specific GIS solutions for professional users* • *lack of flexible modules or GIS data middleware* • *lack of computing power* • *documentation is too technical* • *High performance hardware is too expensive*	• *Introduce users with various data sources and the acquisition method* • *Develop more trainings, avoid technical jargons* • *Develop high reliable and high quality geospatial data* • *Develop software for specific solution* • *Require high-computing GIS* • *Develop more GIS application in new fields (e.g. social media, earth observation)* • *Develop more applications in expert or decision making system*

Based on the results of the questionnaire survey and interviews with field experts, the authors have identified some barriers from these users and their expectations for GIS developments.

- Lack of awareness
- Lack of communication
- Entry cost

- Lack of required software
- Insufficient data sources
- Lacks of computing power
- Usability

4. Potential of Recent Technological Development towards Breaking the Barriers Identified

Having explored the current uses of GIS, identified barriers that prevent its wider appropriation and exposed the potential opportunities; we now discuss the ways to overcome these barriers with relatively recent technical developments.

Open-Source GIS

With the development of Open-Source community, a large number of software tools have been established. Up to present, GIS software and toolkits have published online and allow users to freely download, and has been summarised, see Table 4 (Chen et al. 2010). Open-Source GIS have been developed into a broad range of classification. The main spectrum is shown in Figure 4. Open-Source GIS can be approximately categorised as *Desktop GIS, Spatial DBMS, Server GIS and Web GIS, GIS Library, Database, Spatial Tools, etc.* A detailed classification and information for different types of Open-Source Software has been elaborated by Steiniger & Hunter (2012).

Table 4: The main web sources for Open Source GIS software (from Chen et al. 2010).

No.	Name of sources	URL	Note
1	*Open-Source GIS*	*http://opensourcegis.org/*	over 250 software packages
2	*FreeGIS*	*http://freegis.org/*	more than 300 software packages
3	*SourceForge*	*http://web.sourceforge.com/*	all sorts of GIS
4	*OSGeo*	*http://www.osgeo.org/*	a list of popular GIS packages

There are a number of advantages of using open-source GIS software to break the barriers identified in previous literature and questionnaire sections.

The first being of Open-Source GIS is that it is free to potential users. The free Open-Source GIS allows novice users to understand the basics of GIS with very low entry cost, and in some degree, it promotes the perception of GIS adoption rate. In fact, this is particularly valuable for individuals, small research group, small commercial companies, education sectors, with insufficient funding. Training sessions or workshops are easier by using Open-Source GIS if focusing on different level of users, but there is a barrier as most of current Open-Source GIS manuals are centred on the technical aspect of GIS rather than case study demonstration. In addition, the training courses are often as expensive as GIS training provided by commercial software providers.

The second advantage of Open-Source GIS is original codes are accessible so it is convenient for software modification. This is highly desirable by the high-level users who want to develop their applications. However, the quality of the open-source codes sometimes cannot guaranteed, and it also add additional cost (e.g. learning knowledge, correct the code errors, time for coding) . Detailed and understandable document is a good approach to solve this problem, but as stated before, it is too technical of current documents.

The third advantage is Open-Source GIS is all freely available online, which enhanced the accessibility for users from different regions, e.g. developing countries. The installation volume of Open-Source software is less than commercial GIS Desktop software systems if only selected plug-ins are utilised. The advantages of these technical and economic aspects offer potential for using Open-Source GIS in various organisations.

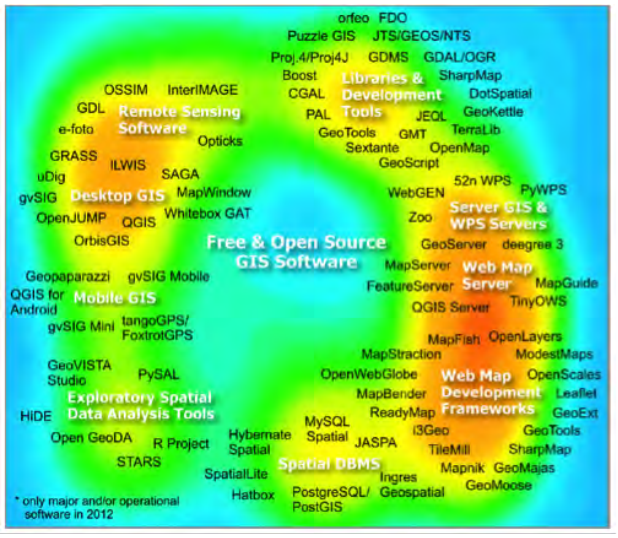

Figure 4: Open-source GIS classification (obtained from Steiniger & Hunter 2012).

Open Data and OpenStreetMap

Geospatial data is at the core of almost all GIS applications. The acquisition of available geospatial data is usually time-consuming, expensive and may be complex. This is mainly due to the disciplinary nature of GIS, as wide range of data is documented

by different organisations with different size, format, specification, etc. In recent years many organisations have started to release rich open data for public or developer use in order to promote GIS application and collaboration. For example Open Street Map and Ordnance Survey's OS OpenData™ datasets (OpenStreetMap 2013, OpenData 2013).

OpenStreetMap is a specific open access data set, basically an online web map, created by volunteers to be freely created, shared and delivered to different communities. The map formats satisfy OGC standards so that they could be used in almost all open-source and professional GIS software. The OSM now includes a wide range of data. For some location-based services application, it is more suitable to use OSM data. OSM has advantages over many professionally created data sources, in terms of access to some data that is difficult for professional surveyors to obtain, such as cycling places, city toilets, etc. OSM can be downloaded as different format on for web-mapping or desktop software (e.g. QGIS and ArcGIS). Even some local government departments have started to use OSM for some GIS projects, such as the Birmingham cycling parking project (Birmingham City Council 2012).

However, it was reported that in 2010 the coverage of OSM was up to 69.8% worldwide and this means that the completeness is still lower than existing commercial products (Feldman & Morley 2012). The data quality of OSM is the main concern with respect to different applications because all mappers are volunteers. In addition, the tags seem sometimes not to be quality checked leading to confusion. A high learning curve is necessary to acquire the data and prepare it so it can be reasonably used in own analysis. A recent study reports that the geometrical accuracy of OSM was assessed between 5 and 10 metres, with higher accuracy in urban areas but low accuracy in rural/deprived areas) (Feldman & Morley 2012). These disadvantage limited the wide spread of OSM which might bring potential opportunities if these issues can be solved.

Cloud Computing

Cloud computing is rapidly emerging as a technology for industries who provide software, hardware and infrastructure. In the field of GIS, the introduction of cloud computing for GIS software and services has become a popular topic. There are several types of deployment scenarios, for example, the ESRI have attempted to develop a Cloud-based platform for Amazon (ESRI 2012). One critical difference between GIS in cloud and traditional GIS is that it could deliver GIS services via the internet, instead of installing and running the software on personal computers. Service users connect to private or public clouds (a set of connected computing computers) and request service from cloud providers (Kouyoumjian 2010). Due to completely different service mode, the future cloud GIS might offer many benefits and some of them might break the barriers of current barriers. The summary in Table 5 organises a set of potential advantages of GIS, as well as the analysis of their potential to break the barriers of GIS.

Table 5: Summary of potential benefits and issues of Cloud GIS.

Cloud features	Potentials of breaking barriers	Potential Issues
shared GIS resources with multiple users	• *promote the GIS adoption, training and information exchange*	• *data leak and privacy*
lower total cost	• *reduce entry (development) cost*	• *still need cost for users*
pay-as-you-go computation	• *reduce entry cost for different users*	• *uncertain benefits for small organisation*
high-speed cloud server	• *satisfy high-speed computation demands*	• *high cost* • *data privacy* • *reliability*

Cloud GIS indeed can potentially provide new benefits based on traditional GIS, such as promoting productivity and reduce cost. Particularly, as the identified barrier of high-computing requirement for professional users, the advantage of cloud computing can help meet this demand are hitting the ceiling of hardware cost, storage space and computation resources (Willoughby 2011). However, some potential issues will be promoted; for example, it is difficult to judge whether it is safe to send data (e.g. sensitive data) onto a cloud server.

5. Conclusions

The research in this paper explored both the barriers that affect the utilisation of GIS and opportunities to overcome these barriers. The research provides a literature review related to the application domains of GIS, as well as the identified barriers. Next, a survey analysis from a pool of selected participants was carried out. The results from survey respondents showed that the applications of GIS still confront many barriers, including: (1) lack of awareness; (2) lack of communication; (3) entry cost; (4) lack of required software; (5) insufficient data sources;(6) lacks of computing power; (7) usability. In addition, many applications are still focused on traditional map presentation and geometry and topology based querying, decision-support and database management as

a high-level functions are still under-utilised.

The research discussed a set of potential solutions to break the barriers and create potential opportunities for GIS development. For example, the development of Open-Source GIS offers a set of rich software toolsets in many different fields that could contribute efficiency and cost-effectiveness for these challenges; such as reducing entry cost, improve accessibility, provide more tools. Open data potentially offers users with free and easy-to-use data. This research addressed OpenStreetMap as a rich data source, but the information completeness is low compared to some commercial products and quality of data is a concern that must be considered. The Cloud Computing potentially provides on-demand and high performance computation. However, it is sensitive to send data to the servers as it causes privacy issue of data owners. In balance, this research provides some ideas to put forward these valuable resources for developing potential GIS solutions in these identified domains.

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