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GIS : Advancement on Spatial Intelligence Applications in Government

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Abstract: A number of approaches for integrating GIS and qualitative research have emerged in recent years. Despite significant growth in public participation GIS (PPGIS) literature since the 1990s, little engagement by e-government scholars is evident in the extensive scholarly PPGIS debates. To fill this void, recent trends in PPGIS adoption by local governments are analyzed. Three waves of GIS are identified: desktop GIS, web GIS, and the Geospatial Web 2.0 platform. Such technological advancements have progressively eased GIS accessibility from expert users to ordinary citizens, accompanied by considerable growth in adopting PPGIS for traffic and transit, volunteered geographic information, and customer relationship management. However, limited use of PPGIS for higher levels of participation such as decision making is found. Barriers to PPGIS adoption for decision making seem less technological and more institutional.

Keywords: Complex system, GIS, spatial computation.

1. INTRODUCTION

Supporting qualitative data and analysis within digital environments is a longstanding concern within GIScience, evident in ongoing research on ways of handling qualitative spatial expressions with spatial technologies [1], as well as efforts to blend GIS with qualitative research, as part of mixed methods research practices [2]. Within these literatures, the discussion has ranged from the practical to the epistemological. Researchers have developed techniques for representing linguistic spatial identifiers within a GIS [3], developed ways to incorporate noncartographic data into geographic information systems [4], and argued that GIS may be used for the inductive exploratory modes of analysis and knowledge production that are typically associated with qualitative research.

A geographic information system (GIS) is a technological tool to depict spatial information visually and to conduct spatial analysis. It integrates spatial data such as polygonal areas, linear elements, and point objects with their attribute data. For example, choropleth maps use thematic colors to depict attributes (such as population) of polygonal areas (such as cities and states). Route maps provide an effi- cient path to reach a destination from a user's location interactively. Th e visual maps simplify the depiction of geographic data that otherwise may be too complex to describe in a narrative or explanatory table. GIS use in local governments has expanded significantly since the 1990s [5].

Public participation GIS (PPGIS) broadly refers to participatory mechanisms involving the general public that are facilitated by GIS. Unlike GIS, which is used for intraorganizational analytic and decision-making processes, PPGIS is extraorganizational, inasmuch as citizens are also involved in collaborative mapping exercises and use GIS for individual or collective decision-making processes. PPGIS has evolved mainly since the early 1990s, when researchers broadened their focus from the technical to the social concerns of GIS [6]. Geographers and planners placed considerable focus on GIS's use for local decision-making processes. Community organizations adopted GIS to empower marginalized groups and communities.

2. GIS IN E-GOVERNMENT

GIS is one of the core technologies facilitating local e-government processes. Although local governments in the United States were slow to adopt GIS during the 1980s, GIS became a common tool in the 1990s—the share of local governments adopting GIS rose steadily from 20 percent in 1990 to nearly 88 percent. With the advent of online GIS,more than 60 percent of municipal websites began to provide "data rich, highly interactive GIS features" [7]. International City/County Management Association surveys show that city/county jurisdictions using GIS programs to create maps and display data increased from 63.4 percent to 73.3 percent. However, fewer local governments provide GIS data online—the proportion increased from 17.2 percent to 33.3 percent during the same period. Community-based organizations also have increasingly adopted GIS to strengthen their informational base and to enhance their advocacy stance with public agencies [8].

Public agencies are not only GIS consumers, but also provide GIS data and influence GIS policies. In terms of GIS use, it "is near the top of the list in terms of utility in almost every aspect of government needs. Despite substantial research on the diffusion of GIS among government agencies, the public administration literature on PPGIS in e-government is curiously thin.

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Filling the gap is important, as a central concern of e-government scholars is to facilitate e-democracy. The various models of the evolution of e-government posit e-democracy as an advanced level of attainment [9]. Encouraging citizen participation and trust in public agencies is a recurring theme in public administration. E-participation is at the core of Garson's [10] model of e-democracy. PPGIS debates are thus relevant to enhancing citizen participation in democratic processes.

3. EVOLUTION OF PPGIS DEBATES

Evolution of PPGIS Debates Social science scholars began to shift focus away from the scientific and technical considerations of GIS applications during the early 1990s. Scholars were critical of the narrow focus on GIS software and hardware requirements, as well as the technical basis of geographic information sciences as a value-neutral and objective method of spatial analysis. Schuurman [11] noted that debates in the early 1990s raged between the technical and nontechnical aspects of GIS, focusing on the positivist claims embodied in the use of GIS as an efficient tool. Whereas GIS proponents extolled the virtues of the newer technical capabilities of GIS for representing geographic space, critics highlighted that the overly technocratic approach carried an imminent threat of naive empiricism without sufficient theoretical analytical rigor.

While raising legitimate criticisms of GIS use, Ground Truth also recognized the disruptive nature of GIS, in which citizens and community groups could utilize GIS to question decisions made by public agencies. The book brought to the forefront the potential of GIS for public participation. As Good child noted, "the field of Participatory GIS has emerged out of this critique, and in many ways owes its existence and its marching orders to the book" [12]. PPGIS took roots among planning professionals and geographers who were keenly interested in public participation as well as GIS. Using PPGIS, community-based organizations have challenged public agencies and provided alternative solutions in several areas, including the environment, natural resource management, landuse, and neighborhood revitalization. In the academic world, PPGIS scholars were initially brought together through the workshops conducted by the National Center for Geographic Information and Analysis (NCGIA) under its Initiative. PPGIS panels have since been held by the PPGIS Congress affiliated with the Urban and Regional Information Systems Association.

The second important work grew out of the NCGIA's specialist meeting in 1998. This volume, called Community Participation and Geographic Information Systems [13], dealt more directly with GIS applications for enhancing public participation than Ground Truth. The book examined PPGIS from several empirical perspectives, including GIS's use in (1) empowering inner city communities; (2) community-based land-use, metropolitan, and rural planning; (3) environmental management by community-based organizations; and (4) empowering marginalized communities. Although the book is indeed significant in bringing PPGIS to the fore from a broader set of perspectives, it lacks an explicit public administration perspective.

Since the turn of the twenty-first century, PPGIS debates have evolved along four thematic lines. The first theme is that of GIS's role in empowerment. The other three (also identified by Sieber [14]) are place and people, technology and data, and the role of institutions. The first theme of empowerment deals with the technological and informational empowerment8 of citizens and community groups using GIS. There is an emphasis on strengthening GIS skills and data collection methods, enhancing local knowledge, and establishing networks. Empirical studies indicate that GIS could empower marginalized groups by facilitating participatory mapping exercises that develop an inventory of customary land divisions and parcel maps [15]. Empowerment may also be limited because of opposition from local leaders and lack of funding, infrastructure, and skilled GIS personnel.

The second theme emphasizes the significance of contextual factors of the place and people participating in PPGIS. Legal, cultural, and political contexts are vital for the extent to which participation really occurs in PPGIS projects. For example, copyright and freedom of information access laws enabled better diff usion of census data for PPGIS use in the United States compared to Canada [16]. De Man and van den Toorn observe that cultural factors such as those resulting from inequality in power and wealth, attitudes toward uncertainty, gender roles, and relationship between individuals and groups (*i.e.*, individualism versus collectivism) affect access to information as well as participatory modes in PPGIS Dwelling on the significance of local political context, Ghose and Elwood show that political relationships among multiple government and nongovernmental agencies at different geographic scales play an interconnected role in PPGIS. With respect to the characteristics of the people who participate, a persistent debate regarding participation in general and PPGIS in particular is the delineation of the boundaries (*e.g.*, geographic or issue based) of who should participate and who constitutes the public [17]. GIS may not easily lend itself to full participation by the public because it requires the intervention of an expert with technological skills to access and manipulate data, an aspect that is important for the next theme, too.

The third theme relates to the technical concerns of PPGIS, including geographic knowledge representation, data access, and data ownership. Technical researchers in Geographic Information Science (GIScience) have been centrally concerned with the specialized aspects of spatial knowledge representation, such as terrain modeling, three-dimensional visualization, aerial imaging, metadata standards, and geospatial analysis [18]. Schuurman argues for extending existing metadata standards to include context-based and tacit information about the semantic attributes of spatial data. Haklay and Tobón highlight the synergy between PPGIS and human-computer interaction to argue that the latter and related usability evaluation techniques can be used to make GIS more accessible for public participation.

The fourth theme is concerned with the role of institutions in PPGIS adoption. The influence of nontechnical institutional factors on information technology adoption is a recurring theme in public administration [19]. The presumption in this strand is that the institutional environment of public policies and laws surrounding access to information, the legal requirements of participation in decision making, and organizational structures and attitudes toward participation influence the adoption of information technologies, including GIS. Debates rage about whether information technology has transformed public organizations in terms of their structures or redistribution of values and power [20]. In her exploration of Internet adoption by government agencies, Fountain observes that technology is adopted within a technology enactment framework, in which "the embeddedness of government actors in cognitive, cultural, social, and institutional structures influences the design, perceptions, and uses of the Internet" [21]. As explained later, the institutional conditions are indeed crucial for PPGIS adoption in decision-making processes.

4. EVOLUTION OF PPGIS DEBATES

Once labeled "elitist," GIS has expanded from the domain of expert users to become more user friendly and more accessible to ordinary citizens. Broadly, three distinctive waves of GIS evolution can be identified. The first wave is traditional desktop-based GIS, which encompasses stand-alone GIS applications running on personal computers. These GIS applications offer powerful methods of producing maps on the fly, integrating spatial and attribute data. Unlike static maps, GIS maps are more dynamic, allowing for search, pan, and zoom functions to obtain maps based on the user's parameters. These maps are typically vector based, and are also useful for conducting spatial analysis (*e.g.*, point patterns, clustering, neighborhood relationships, path analysis). Stand-alone GIS, however, requires expensive software installation and sufficient GIS skills (including knowledge of spatial analysis) to manipulate the maps. Hence, stand-alone GIS requires a GIS expert to intervene between public agency officials and citizens in the process of public participation.

The second wave is web GIS (also referred to as online GIS or Internet GIS), wherein GIS has become integrated with the Internet since the 1990s. Web GIS added more capacity to traditional GIS. In web GIS, the public agency typically hosts the GIS software and data on its servers. The thematic maps and data are then deployed to client computers over the Internet. The maps are thus accessible to anyone on a computer with an Internet connection. The advantage of web GIS over desktop GIS is that it is more accessible to the general public, as citizens do not have to install expensive software on their computer. Citizens can view the maps in real time with dynamic data queries. The interactive features of web GIS, such as querying, searching, and mapping dynamically on the fly, have further expanded the use of GIS for citizen participation [22]. Web GIS holds more potential for PPGIS than traditional desktop GIS because the data are more accessible to a broader set of citizen groups. The main disadvantage of web GIS for public participation is that a public agency needs to have in house expertise and financial resources to implement it.

The third wave of GIS is the adaptation of web GIS to the Web 2.0 environment in what is called the Geospatial Web 2.0 platform. The Web 1.0 environment is associated with basic information dissemination by servers to clients through static web pages (typically using hyper text markup language, or HTML). Web 1.0 serves customary information published and owned by the producers. Unlike this one-way server-client relationship, Web 2.0 is associated with serving two-way dynamic content. The Web 2.0 is a platform that facilitates the harnessing of collective intelligence through blogs, wikis, podcasts, Twitter, and social networking sites. In Web 2.0, Extensible Markup Language (XML), which allows for sharing structured data, is more prevalent than HTML [23]. Geographic Markup Language (GML) is an XML-based coding scheme that allows the exchange of geospatial data. A key feature of Web 2.0 is the mashup, an independent third-party program that can be used to overlay information from multiple Internet sources into one web service using application programming interfaces (APIs). As a result of API interfacing, interoperability issues are far less pronounced in Geospatial Web 2.0 platforms than those using the traditional desktop GIS or web GIS. Lake and Farley define the Geospatial Web 2.0 platform as "the global collection of general services and data that support the use of geographic data in a range of domain applications". It is characterized by two central features. First, it enables locationbased search (as opposed to traditional text-based search). Second, GIS applications need not be hosted by one agency; rather, GIS data can be overlaid on other existing map servers through mashups. For example, Google Earth, Google Maps, Microsoft Live Search, and Yahoo! Maps provide a base platform for other GIS applications to be added on. Public agencies can take advantage of cloud computing (*i.e.*, mount their data on third-party servers) to provide spatial information.

From a PPGIS perspective, the strength of the Geospatial Web 2.0 platform for enhancing citizen participation is that it can be intuitively used by ordinary citizens [24]. Users can also add information to the online maps. With the newer generations of smart phones (equipped with both GIS and GPS capabilities) and social networking sites such as Facebook, the Geospatial Web platform has the power to harness public participation in real time. Local governments, citizens, and businesses can receive as well as send location-specific information using multiple media (*e.g.*, videos, text, maps, sound) in real time. Sui [25] refers to this as the "wikification of GIS," which is driven by large-scale, voluntary collaboration among both amateurs and experts using Web 2.0 technology. Such information sharing and development has implications for local e-governments for several purposes, such as citizen relationships, park management, economic development, and transportation management, to name a few.

Despite the ease, there are also caveats of the Geospatial Web 2.0 platform for PPGIS. First, the server-side scripting of mashups requires a degree of computer expertise; hence, although the Geospatial Web 2.0 platform may be intuitive to users, deploying it for municipal services requires in-house technical expertise. Second, the separation of the GIS platform from local government data brings about ownership and property rights issues. Third, there are issues of geographic privacy when local governments use the Geospatial Web 2.0 platform as the primary agent of online spatial information.

5. PPGIS APPLICATIONS IN E-GOVERNMENT

With GIS technology becoming more user friendly and accessible, local governments have adopted it in various ways. Four areas of PPGIS use in local governments are examined here: traffic and transit information provision, volunteered geographic information, customer relationship management, and decision making. There is much growth in adopting PPGIS in the first three areas for providing information. However, the use of PPGIS in decision making has yet to gain a significant foothold. While growth in the first three areas could reflect citizen demand and local governments' priority for such online applications in an era of tight budgets, the limited GIS use in decision making is likely attributable to institutional constraints.

The Internet has revolutionized accessibility to geographic information. Web GIS and Geospatial Web 2.0 maps provide real-time information over the Internet. Such maps have been increasingly adopted to report traffic conditions and to provide directions. MapQuest, for example, provides thematic maps of traffic for 85 metropolitan areas that are updated every five minutes [26]. Other major Geospatial Web 2.0 platforms (Google Maps, Yahoo! Maps, Microsoft Live Search) provide similar services. These services have been increasingly used by state and local agencies. Florida's Department of Highway Safety and Motor Vehicles, for example, uses Yahoo! Maps to give driving directions to the driver's license office after citizens make an appointment online. Citizens can use Geospatial Web 2.0 platforms to report traffic incidents in real time. On one hand, such information enables the public to make more informed decision about travel routes; on the other, local governments can harness such information for incident management.

Rapidly growing use of Geospatial Web 2.0 platforms is most evident in the context of providing information about public transit. Google Transit especially has transformed the way information is provided by transit agencies. It is a free service that was integrated with Google Maps in 2006. In the absence of Google Transit, transit agencies typically provide static maps of bus and train routes, with an accompanying schedule of their arrival and departure times. Alternatively, transit agencies may develop web GIS maps in house. However, with Google Transit, transit agencies need only provide information on stops, routes, and schedules in comma-delimited text fi les that require little computer skills. Google Transit then integrates the data on Google Maps to provide transit options to users. Google Transit is also advantageous for coordinating between neighboring transit agencies to provide connectivity. Although the adoption was initially slow, nearly 420 agencies worldwide had adopted Google Transit as of July 2009 for providing information on public transportation [27]. Google maintains that the Transit program attracts new riders and increases agency awareness and web traffic. The Hampton Roads Transit (Virginia) website attracted 60 percent more page views after the agency adopted Google Transit; the web page hosting the Transit trip planner accounted for nearly 7 percent of the page views [28].

5.1. Volunteered Geographic Information

Volunteered geographic information (VGI) refers to "the explosion of interest in using the Web to create, assemble, and disseminate geographic information provided voluntarily by individuals" [29]. Unlike traditional maps, which require professional geographers and cartographers, Web 2.0 developments and GPS devices enable amateur citizens to generate and share geographic information quickly over the Internet. Smart phones and cameras (with embedded GPS devices) can be used to geocode and document events and incidents through pictures that can be shared quickly using social networking. Goodchild argues that citizens are a "large collection of intelligent, mobile sensors, equipped with abilities to interpret and integrate that range from the rudimentary in the case of young children to the highly developed skills of field scientists" [30].

Prime examples of user-generated geographic content include Wikimapia and OpenStreetMap. Wikimapia is similar to Wikipedia, but adapted to geographic information; it is an "online editable map allowing everyone to add information to any location on the globe" (http://wikimapia.org). Any person can upload a description of a selected spot in the world, including links to other sources. Others can review the descriptions for accuracy, edit the entries, and volunteer additional information. OpenStreetMap is a free map of the world that can be edited by anyone with an Internet connection. It is a voluntary effort to create local maps through collaborative mapping projects distributed throughout the world. In addition, Flickr, a photo-sharing service with geotagging capabilities, enables photographs to be overlaid with latitude and longitude information, so that the photographs can be associated with a location.

VGI has several implications for PPGIS and e-government. The participatory GIS efforts of including citizen volunteers to provide geographic information widen the domain of map making from professionals to ordinary citizens and facilitate democratization of GIS [31]. Cinderby and Forrester argued that "an ideal form of PPGIS could be where neighbourhood residents collect their own spatial data and process it themselves using GIS software". Seeger [32] demonstrated the application of usergenerated spatial information for participatory landscape design and planning. Gouveia and Fonseca proposed the Environmental Collaborative Monitoring Networks framework, which combines traditional environmental monitoring methods with those of voluntary citizen monitors. In disaster contexts, residents have better local knowledge about the ground situation and have the potential to provide such information for coordinating quick action in concert with government entities.

From an e-government perspective, VGI holds the potential for collaborative map making that goes beyond traditional agency domains. The voluntary efforts of mapping are worthwhile at a time when mapping efforts through national surveying and cartographic agencies are declining [33]. The U.S. National Research Council highlighted the need for a spatial data infrastructure that provides standards and protocols for geospatial information, so that private and voluntary groups can generate and update maps at various scales based on their needs. Although Goodchild viewed VGI as fitting the spatial data infrastructure model, Flanagin and Metzger expressed skepticism about the credibility of such information. Further, Tulloch acknowledged overlaps between PPGIS and VGI, but argued that the two diverge insofar as the former is concerned with process and outcomes, and the latter is concerned with applications and information.

5.2 Citizen Relationship Management

Many local governments have made jurisdictional information available online using web GIS. The basic web GIS maps include street layouts, sites of tourist interest, and real estate information. More advanced web GIS maps include political boundaries within the local government (*e.g.*, wards, council districts), thematic maps depicting demographic and socioeconomic information, natural environment sites (*e.g.*, watershed, forest areas, floodplains), land use and zoning, parks and recreation, and transportation and utility services. Agency-specific web GIS maps are specialized in providing information that falls within the agency's domain. For example, property appraiser offices in local governments often provide public domain information such as property appraisal, tax, and related information using such web GIS maps.

The availability of geographic information over the Internet allows for increased efficiency as well as transparency in the delivery of local government services. The advent of web GIS and Geospatial Web 2.0 platforms has increased the capacity of local governments to integrate GIS with citizen relationship management (CRM) and to deliver local government services. In the United States, for example, CRM systems are crucial to 311 call centers, which are centralized local government public information centers that take nonemergency service requests from citizens. CRM enables 311 systems to route requests to the appropriate department and follow through on the fulfillment of service requests. The integration of CRM with GIS allows geographic tracing of citizen demands for specific local government services (*e.g.*, pothole repairs, trash removal). As an report highlights, "integration of 311/CRM data into a local government's geographical information system (GIS) technology is critical to understanding where and what type of service requests are being made in a community" [34].

GIS analysis could also assist in raising public awareness to reallocate resources according to need. For example, clustering of a number of pothole repair requests from the same neighborhood could be indicative of generally poor road conditions in the area, which may require broader intervention from the city's infrastructure department to repair the roads. In Minneapolis, for example, GIS analysis of the city's Regulatory Services Department service requests showed that two districts had the same number of supervisors and support staff, although one had twice the number of exterior nuisance service requests.

In China, public access to online maps has been useful for delivering improved services to local communities through the integration of GIS with public services. FixMyStreet is an online service developed in 2010 by mySociety, a nonprofit group funded by the Department for Constitutional Affairs Innovations Fund. Using the service, citizens can report local physical problems (*e.g.*, graffi-ti, unlit lampposts, abandoned beds, broken pavements) by locating them on an online map and giving an appropriate description (and photographs). These reports are then routed to the appropriate local government for redressing problems. Citizens can also trace updates on their request online. As of July 2009, nearly 25,000 problems had been reported through the FixMyStreet service, according to the website. photographs). These reports are then routed to the appropriate local government for redressing problems. Citizens can also trace updates on their request online. As of July 2009, nearly 25,000 problems had been reported through the FixMyStreet service, according to the website.

5.3. PPGIS Use in Decision Making

Although the first three areas of PPGIS are significant technological developments, they are principally related to the domain of geographic information provision. While citizens can participate in such information provision and act on it, these three areas are not related to participatory decision making. Arguably, these areas cannot be considered to have high levels of public participation, in terms of Arnstein's seminal "ladder of participation" concept and its subsequent variants [35]. In this conceptualization, information provision and feedback are at the lower levels of participation. Informing and consultation may use informational tools such as maps, aerial photographs, and interactive websites for public comments. Higher levels of public participation would include involvement, collaboration, and empowerment, wherein citizens "know that their participation has the potential to have an impact" [36].

Rational decision-making models involve several dimensions. Simon identified four steps: intelligence (collecting information and data), design (identifying alternative solutions), choice (selecting an alternative), and review (implement and monitor solution). Rational planning models involve five steps: problem identification, analysis, evaluation, choice of strategy, and implementation and review. In terms of participatory decision making, Renn *et al.* used a three-step process combining technical expertise and rational decision making: criteria development (with stakeholder involvement), options generation (with experts), and options evaluation (with citizens).

A notable implementation of PPGIS for decision making is the regional planning process undertaken by Metro, an elected body of the Portland metropolitan area that comprises three counties and 24 cities. Established in 1978, the Metro initiated regional planning for managing the area's growth over the next 50 years (the Region 2040 program). The Metro developed the Regional Land Information Systems (RLIS) program in 2010 as a GIS database with detailed parcel level information. Residents were supplied with the data and software in order to access city maps, so that residents can perform their own analysis, interpret the results, and make policy suggestions. The RLIS has since been adapted to the Internet for broader accessibility and public participation. The Metro used a Geospatial Web 2.0 platform (Google Maps) in 2010 for eliciting public participation in planning the region's high-capacity transit system [37].

CONCLUSION

Although e-government scholars are centrally interested in enabling e-democracy, there is a dearth of public administration literature on enabling public participation using GIS technology. This article has outlined some of the major ways in which GIS has been tapped for public participation by local governments, drawing on the thicker PPGIS literature. Th ere are crossovers between PPGIS and e- government, as many of the PPGIS themes are relevant for e-government. GIS technologies have progressively become more accessible and user friendly, thus increasing their potential for inclusion in e-government processes for enhancing public participation. There are three waves in the evolution of GIS technology for public participation: desktop GIS, web GIS, and Geospatial Web. The waves represent progression of the GIS technology from being an elite field of expert professionals to that of ordinary citizens.

The article also identified the major ways in which the advancements in GIS are useful for public participation. First, GIS has enabled local governments to tap into web services such as Google Maps to provide traffic and transit information. Google Transit is the prime example of such use. Second, the Internet has enabled significant growth in volunteered geographic information; local agencies can tap into local knowledge to enhance participation for various purposes. Third, GIS has increasingly enabled local governments to undertake customer relationship management in a more efficient way. Citizens can report local problems online, which are then routed to the appropriate department to address. However, these represent uses in lower levels of public participation; the potential of GIS for higher levels of public participation is yet to be achieved. Other than the Metro in Portland, few local governments have used GIS in decision-making processes. The barriers to GIS adoption for decision making are less likely to be technological, and more likely to be institutional.

Other limitations and caveats of GIS use in public participation must also be acknowledged. First, GIS is among a family of tools to elicit public participation. It deals with the spatial element in participation; however, other elements of participation (*e.g.*, dialogues, pictorial representations, etc.) also need to be taken into account in a wholesome participatory process. Second, public participation as well as spatial representations are context specific, influenced by local cultural, institutional, and political factors. As e-government scholars have argued, technology adoption is shaped within an organizational and institutional context. Hence, although GIS may enable empowerment of local knowledge, the specifics of who is empowered need to be examined within the context in which public participation is elicited.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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