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Evaluating Local Government Usage of GIS: A New Maturity Model

Completed Research Paper

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Abstract

GIS is a technology with the potential to transform government by enhancing business processes and providing a platform to manage spatial and non-spatial data, which is expected to result in better decision-making. However, little is known about how this technology is actually implemented organization-wide and the environment surrounding its use. Current GIS maturity models have not examined usage broadly or in-depth, lack empirical validation, and measurement tools to diagnose maturity are not readily available. Based on GIS, maturity models, and system usage literature this study presents a more comprehensive maturity model for evaluating local government usage of GIS along with a measurement tool. The study followed De Bruin guidelines for developing maturity models. This new model was discussed with practitioners and academics, was pilot-tested, and then widely tested on Southern California local governments through an online questionnaire. Results show support for the validity of the model and demonstrate its utility.

Keywords: GIS, System Usage, Maturity Models, Local Government, Organizational Perspective, Stages of Growth.

Introduction

Geographic Information Systems (GIS) can be defined as a "set of computer-based tools that allows the user to modify, [store,] visualize, query, and analyze geographic and tabular data" (Santos 2012). GIS have first appeared around the 1960s in the Canadian government to manage some of its resources and was led by Roger Tomlinson who was a pioneer in GIS (Foresman 1998). Since then, GIS has become a standard technology in the technology toolbox of almost every level of government worldwide (Longley, Goodchild, Maguire and Rhind 2010). GIS is moving towards a wider array of customers from the public sector to corporations, grassroots organizations, and non-for profit organizations. Optimistic estimates report that up to 80% of data stored in government databases contain a spatial component (Worral 1991) but this number should be taken cautiously as no empirical evidence is ever presented for this number. The majority of a local government's work revolves around geography (e.g., planning, facility management, taxation, property maintenance, crime analysis, environmental monitoring). Constant changes in policy, and the dynamic flow of information, demand a shift in e-government focus from merely digitization and online presence into transformative governance grounded on the basis of open data, public participation, more transparency, modernization of public services, and citizen engagement (Zhang 2012). GIS has the potential to carry out some of these transformative initiatives by better and informed decision making through location analytics that builds towards smarter cities (Roche 2014). GIS and Spatial Data Infrastructure (SDI) enables e-government development by forming the backbone (on the back-end) for online portals (Turner and Higgs 2003; Vancauwenberghe, Crompvoets and Vandenbroucke 2014; Zhang 2012).

Despite the extended history of GIS in government and expanding usage in business, the impact of GIS has not been fully realized as reported in recent studies (Gudes, Mullan and Weeramanthri 2015; Ye, Brown and Harding 2014). Even older studies have raised concerns about the benefits of GIS beyond basic mapping and spatial data management inferring underutilization of GIS capabilities (French and Wiggins 1990; Turner and Higgs 2003). As such, the extent of organizational usage of GIS (functionalities used, processes enabled, users supported) at local government remains difficult to measure and diagnose.

Though there could be numerous reasons for unsatisfactory outcomes and expected results related to a GIS (e.g., poor system implementation), system usage should be the factor to consider first. If systems are not used, then how can quality, reliability, value, usefulness, ease of use, or user satisfaction be assessed? System usage is the “employment of one or more features of a system to perform a task” (Burton-Jones and Straub 2006) at the individual, group, or organizational level. In the Information Systems field, system usage has received substantial focus in relation to IT investments and business value. DeLone and McLean (2003) in their very popular IS success model, acknowledge the association between ‘system use’ and ‘individual and organizational impact’. Other researchers have also identified system usage in specific settings as a precursor to system’s impact (Devaraj and Kohli 2003; Goodhue and Thompson 1995; Markus 2004).

Post implementation understanding of GIS usage is needed. Without properly understanding current GIS usage practices, improvement is difficult as the ‘as is’ state is not known. Thus, aiming for a specific GIS value without satisfying certain levels of organizational usage of GIS seems unfeasible. The multi-user, multi-purpose, nature of GIS makes it difficult to assess organizational usage of the technology. The environment surrounding GIS (either supporting or hindering usage) is complex and has not been deeply examined.

Maturity models are “conceptual multistage models that describe typical patterns in the development of organizational capabilities” (King and Teo 1997). Maturity models assume linear progression from a less mature state to a more mature one in a manner that cannot be easily reversed or skipped (Lavoie and Culbert 1978). Maturity is depicted as quality of a process, growth in some factor or an improvement in a capability (Mettler 2011). Maturity models were developed in academia and then utilized by practitioners and consultancy firms due to their ability to simplify complex reality, making them helpful for diagnosing an organizations’ maturity. IT maturity models evaluates the organization comprehensively as one unit to assess its maturity. This approach aligns perfectly with the objective of this research in assessing organizational use of GIS.

This study seeks to answer two main questions: what are the dimensions necessary to include in developing a usage based GIS maturity model? And how would it be measured? The study evaluated these questions by examining the state of GIS maturity in Southern California local governments using the proposed maturity model via a questionnaire to empirically validate it.

The objective of this work is to design a comprehensive GIS usage maturity model for benchmarking and evaluating e-government efforts in utilizing GIS technology. The model would be used to diagnose the current ‘as is’ state of using GIS in local governments through a simple and quick measurement tool.

Related Work

In order to comprehend the construct ‘system usage’ in the GIS domain, the nature of this study draws upon diverse but related literature. The literature on system usage is examined to understand the scope of this construct and what needs to be measured. Next, this study looks at the studies of GIS usage to understand the context that surrounds GIS. Lastly, this study looks at GIS maturity models to extract what is relevant for evaluating maturity with regards to the usage of GIS.

System Usage

The initial goal of any computer system is to be used by its designated targets. System usage has received substantial focus in the field of information systems. This construct has been used as an independent or dependent variable for a plethora of theories and frameworks (Burton-Jones and Straub 2006). It has been used to indicate success (of implementation, acceptance, adoption or diffusion) as in the Information System Success Model and its variants (Delone 2003), Technology Acceptance Model (Davis 1989) and its counterparts and the Diffusion Of Innovation Model (Rogers 2010). System usage is also used as a precursor to performance impact (when fit exists between technology and task) (Goodhue and Thompson 1995). System usage has been studied at the individual level (single user, customer), group, and organizational level.

The literature on the construct 'system usage' has relied on different measures (e.g. extent of use, frequency of use, duration of use, variety of use) to operationalize the construct at the individual level. Proxies such as (user satisfaction) were also used to measure usage. This has led partially to mixed results in the literature about the impact of system usage on other constructs. The measures are usually self-reported or derived from system logs. The system usage construct isn't well understood on the individual or the organizational level (Burton-Jones and Gallivan 2007).

Research on organizational system usage is scarce. Devaraj and Kohli (2003) defined organizational usage as the aggregate of individual use specified as the number of reports generated, number of records accessed, and CPU processing time to assess the payoff of a Decision Support System (DSS) for hospitals. Ruivo, Oliveira, and Neto (2012) used the same operationalization but in the context of ERP which they measured by the number of employees using the system daily, percentage of time per day that employees spend on the system, and the number of reports generated per day. Other researchers represented organizational usage as the extent of using Information Technology (IT) for decision support (problem solving and decision rationalization), work integration (horizontal and vertical) and customer service (Doll and Torkzadeh 1998). Massetti and Zmud offered a more comprehensive operationalization of organizational usage in the context of Electronic Data Interchange (EDI) as volume (extent of documents exchanged), diversity (types of business documents handled by EDI), breadth (EDI connections with trading partners), and depth (business process tied with trading partners through ED). Other researchers have picked up this conception and utilized it for ERP (Jonas and Bjorn 2011) and mobile commerce usage (Picoto, Bélanger, and Palma-dos-Reis 2014). This study uses the ideas of (Massetti and Zmud 1996) and adapt them to GIS in the manner of (Jonas and Bjorn 2011) by considering process where GIS is used and level of management supported. Organizational system usage measures vary by case and lack consolidation.

Burton-Jones and Straub, in a widely cited paper, made an attempt at reconciling the literature on system usage by outlining three dimensions of system usage. The first dimension called the user "individual person who employs a system in a task (Burton-Jones and Straub 2006)", the task "goal directed activity provided by the user" (Burton-Jones and Straub 2006), and the system "artifact that provides representation of one or more task domains" (Burton-Jones and Straub 2006) on a scale from lean to rich depending on the objective of the research (Burton-Jones and Straub 2006). Due to the complexity of GIS usage, this study believes that it needs a rich measure of system usage and as such, will employ 'user, 'system', and 'task' as dimensions of system usage.

GIS Studies

The majority of the studies in this stream of research were interested with the factors facilitating or hindering adoption/diffusion and use of GIS (Brown 1996; Göçmen and Ventura 2010; Ventura 1995). Case studies are used to present the experience of one organization using GIS (Alrwais and Hilton 2014; Hussain, Ramzi and Johar 2010) or surveys are used to provide a report on the extent of use (Higgs, Smith, and Gould 2005; Olafsson and Skov-Petersen 2014). The majority of these studies are "subjective accounts describing the benefits of GIS from a single-user perspective" (Brown 1996); few have looked at the organizational level. Portions of them are old and conducted outside the USA, which questions their current validity. More importantly this study did not find any attempt to consolidate the findings of these studies into classifying GIS usage. Still this literature serves to provide some empirical GIS usage variables.

Calkins and Obermeyer created a taxonomy to survey the use and value of GIS in decision making. The questions that pertain to GIS usage at the organizational level in local government are those focusing on the purpose of using GIS (inventory, analysis, or decision support), the GIS capabilities required (display of geographic data, query, direct measurement, map overlay, network algorithms, and spatial models), users of geographic data or information (analyst, middle management, upper management, general public, or public opinion groups), and management level of user (operations, management, or policy) as described in (Calkins and Obermeyer 1991). When talking about GIS use in local government, O'Looney also emphasizes the need to clarify the purpose of using GIS (inventory, analysis, or decision support) and the complexity of the task from simple queries to complex what if modeling (O'Looney 2000). Croswell reviewed 39 articles that discussed obstacles to GIS implementation and identified 11 groups as general obstacles of which training, staffing, and top management support applies to this study. Related research that came after Croswell's work supported these 11 obstacles and especially the organizational barriers (training, staffing, awareness, and top management support) over human or technology barriers [see for example Brown 1996; Göçmen and Ventura 2010; Higgs et al. 2005; Ventura 1995].

The importance of having a special purpose department for GIS was supported by (Budic 1993) when she demonstrated that having such a department raises significantly the number of departments using GIS (4 departments compared to 1.5 without the GIS department). More recent studies also support the importance of having a dedicated GIS unit on the use and development of GIS within that organization (Alrwais and Hilton 2014; Borges and Sahay 2000; Olafsson and Skov-Petersen 2014). A group of researchers have defined a set of metrics for the success of an enterprise GIS based on a case study (Witkowski, Rich and Keating 2008). One metric that has a direct bearing on GIS usage is the number of data usage agreements signed with external agencies (Witkowski et al. 2008).

Maturity Models

As briefly discussed in the introduction, maturity models in information systems attempt to describe the maturity of an object (quality of a process, technology, data, or management activities) through a sequence of stages (levels of maturity states from low to high) determined over a set of dimension/s defined over some benchmark variables. Although there have been about 128 new maturity models developed over the past years (Wendler 2012), the study was able to identify only one paper in the IT maturity literature that discussed usage maturity (Holland and Light 2001). Holland and Light proposed a usage maturity model for ERP use where they examined the consequences of maturity (result) instead of examining the antecedents of maturity (process or infrastructure). Holland and Light proposed five dimensions for ERP usage maturity of which two (the level of penetration of a system and the vision behind obtaining a system) will be utilized for GIS usage maturity as the other three dimensions are specific to ERP and apply more to the private sector.

GIS Maturity Models

GIS has its share of maturity models. Between the periods of 1996-2014, research was able to devise 12 different models. Not surprisingly, most of the models were developed and applied to local government due to its long, historical, use of GIS and thus many variations of maturity would expected to be found. Table 1 summarizes the available GIS maturity models.

	Kurwakumire 2014	**Exprodat 2013**	**URISA 2013**	**Makela 2012**	**Giff 2012**	**Loenen 2008**	**Keel 2008**	**O'flaherty 2005**	**Tomaselli 2004**	**Chan 2000**	**Grimshaw 1996**	**Marr 1996**
Name of the model	Public sector GIS evaluation methodology	GIS maturity model	GIS capability maturity model	GIS maturity model	Online self assessment methodology for SDI	Assessment Of SDI	MM for Enterprise GIS	Stage model for GIS and SDI	Enterprise model of GIS	A 3 stage development of corporate GIS	GIS management strategies	GIS maturity & integration
Unit of analysis	Public organizations	Business organizations	Local government	Public Organizations	Local SDI members	SDI	Business organizations	Local government	An organization	Business organizations	Business organizations	An organization
Dimensions explored	- Information - Availability of data - Access to data	- Business awareness & governance - Spatial data management & integration - GIS technology - GIS training - Use of GIS	-Technology - Data - Process - Staff - Organizational structure	- Architectures - Services & processes - Capabilities	- Organizational structure - Information management -Technology -Process -Customer service	Organizational settings	-Alignment -Data management -Accessibility -Integration -Sustainability	N/A	N/A	N/A	-Strategy -Structure -Systems -Staff -Style -Skills -Shared values	N/A
Empirically tested?	Yes, but results are not presented	N/A	Yes	Yes	Yes, but results are not presented	No	N/A	No	No	Yes	Yes	Yes
Measurement tool disclosed?	No	No	Yes	No	No	No	No	No	No	No	No	No
Major findings	A value driven GIS evaluation model of intangible benefits	A comprehensive framework for a GIS strategy	A complete documented model with resources	A model with rich content	+200 indicators of maturity	Adds to SDI the organizational component	Definitions & characteristics of stages towards enterprise GIS	Describe interplay between GIS and SDI management activities	Description of enterprise GIS, components its barriers and implications	Long term patterns in the development of GIS	Different GIS strategies for each stage of maturity	A computational amalgamated indicator of maturity
Maturing object	GIS benefits	GIS strategy	GIS capabilities (operation)	Competence in using spatial data	Utilization of SDI	Organizational structure	GIS capabilities (operation)	N/A	N/A	GIS management	GIS management strategies	Use of GIS
Stage names	1)Grass-root 2)Intermediate 3)Mature 4)Integrated	1)Initial 2)Recognizing 3)Defining 4)Managing 5)Optimizing	1)Ad-hoc 2)Repeatable 3)Defined 4)Managed 5)Optimized	1)Decided case-specifically 2)Separately governed 3)Concentratedly coordinated 4)Comprehensively managed 5)Strategically optimized 6)Innovative	Level1 Level2 Level3 Level4 Level5 Level6	1)Stand-alone 2)Exchange 3)Intermediary 4)Network	1)Enthusiasts 2)Departmental 3)Central 4)Integration 5)Enterprise	1)Early implementation 2)Growth 3)Control 4)Stability	1)Awareness 2)Development 3)Acknowledgment 4)Support 5)Enterprise	Stage1 Stage2 Stage3	1)Opt-out 2)Stand-alone 3)Linking 4)Opportunistic 5)Corporate	N/A

Table 1. GIS Maturity Models

Grimshaw discusses the evolution of GIS strategy over five stages using seven elements to describe each stage of which strategy, structure, staff, style, and skills are used as it relates to organizational usage of GIS (Grimshaw 1996). Other researchers have attempted to quantify GIS maturity using six variables (Marr and Benwell 1996) of which three (number of uses which GIS is assisting, number of departments using GIS, and the department responsible for GIS) that fit with usage are often used. Linda Tomaselli proposed her own five stages of GIS maturity by focusing on various people's aspect of maturity. She outlines the importance of having a GIS champion, using consultants, hiring qualified GIS staff, and breaking the barriers preventing departments from sharing spatial data (Tomaselli 2004). Other researchers have developed another GIS maturity model composed of four stages by focusing also on the human aspect of GIS (O'Flaherty, Bartlett, Lyons, Keanko, Ending and Schulz 2005). Loenen and Rij analyzed the evolution of GIS at the state and regional level, referred to as Spatial Data Infrastructure (SDI); they proposed a four-stage model with an organizational perspective encompassing six organizational factors (Van Loenen and Van Rij 2008). In the context of GIS usage at the local governmental level, vision of GIS, and GIS awareness are important organizational factors and thus will be part of the study model. "Even Keel Strategies", a consulting firm, developed a 5 stage GIS maturity model over 7 factors of which accessibility to all user levels and relevance of GIS to operational workflow will be used in the study model (Mangan 2008). Jaana Mäkelä offered a more comprehensive GIS maturity model made of 6 stages depending on architecture, services and processes and capabilities as key areas (Mäkelä 2012). From the list of factors, spatial data in internal core processes, support processes, and internal cooperation within the organization (Mäkelä 2012) will be used in the model as it relates directly to GIS usage.

URISA's GIS maturity model focused on optimizing GIS operation (quality of GIS processes, enabling capability, and execution capability), which is quite different from this work as it relates to the actual usage and application of GIS within an organization (Center 2011). However, the variables concerning GIS staff, GIS training, GIS governance structure, and GIS strategic goals (Center 2011) are related to this work and thus will be used. Exprodat, a GIS consulting firm in the petroleum industry, proposed a five stage GIS maturity model over six indicators of which GIS awareness, GIS training, GIS functions used are good indicators to be used in the model (Exprodat 2013). Giff and Jackson take a comprehensive approach to the governance of GIS and propose six levels of geospatial data maturity (Giff and Jackson 2013) of which strategy, governance, business work use, integration with workflow, and GIS training are appropriate to be included in a GIS usage maturity model. Kurwakumire evaluated GIS maturity in terms of benefits gained of which the level of geospatial information communication (as a map, report, presentation or a decision tool) seems appropriate to be included in the model (Kurwakunire 2014).

Although all of these models aim at describing maturity of GIS, it was not always clear what was "maturing". Is it the technology, infrastructure, process, management of GIS, or service provided by GIS? Although some of these models aim at describing maturity in using GIS, their benchmark variables (process area, critical success factors, and best practices) don't correspond tightly with GIS usage. Some of those models cover a wide range of perspectives that it's questionable to label it as a maturity model where in fact they are more of an IT/GIS management framework. The purpose of maturity models is to develop a simple yet comprehensive method of diagnosing an organization's maturity (Wendler, 2012), but except for URISA none of the other models disclose the measurement tool.

Table 1 provides some of the limitations in existing GIS maturity models. Some of these models are not empirically tested beyond the cases that formed the model. Another issue is that the measurement tool is missing which limits its practical use. Except for Exprodat's model, use of GIS is not considered part of maturity. Even Exprodat's model does not provide details about how to measure GIS usage. Another important issue is that some of these models assess the state or countrywide maturity of GIS (SDI) while in this study the scope is the individual city or municipality using GIS. These models emphasize to a great extent the infrastructure, technology, data, management activities, and policies associated with GIS yet they place little effort in evaluating the actual usage and application of GIS. The organizational usage of GIS and the environment surrounding it has been under-studied and no measurement tool exists to-date to measure organizational usage of GIS. The view of this study is that having a state-of-the-art quality operational GIS alone is not sufficient to indicate maturity. This study asserts that the actual use of GIS resources by the organization is a more accurate indicator of GIS maturity and thus it attempts to develop such a model.

Description of the "GIS Usage Maturity Model"

Mayr defines GIS maturity as "the degree to which systems are actually used" (Mayr 1995) while (Giff and Jackson 2013) base their maturity model on geospatial information usage. Others propose that maturity is "linked to the level that GIS has been integrated and utilized on an organization wide basis in day-to-day activities" (Marr and Benwell 1996). From this, this study defines GIS maturity as the 'extent of usage and absorption of GIS within an organization' and uses this definition as a foundation for the proposed model. Next this study describes the dimensions used in the model then presents the content of the maturity model.

Dimensions

As illustrated earlier, Burton-Jones and Straub outlined the importance of using a rich measure for system usage that includes the system, task, and user at the individual level. This study takes this conceptualization of system usage and applies it to GIS usage but at the organizational level. The study followed the logic of the systems approach (Churchman 1979) in forming the model in that in order to understand a system you have to inspect the elements that make up the system and the environment within which this system operates with linkages between them. Thus, this work adds two additional dimensions to system usage: the organization dimension and the GIS department dimension. GIS maturity models acknowledge the implication of organizational variables [strategy, vision, training, funding, collaboration, etc.] (Giff and Jackson 2013; Grimshaw 1996; O'Flaherty et al. 2005; Van Loenen and Van Rij 2008). Thus, this study considers the organizational configurations as an independent dimension of maturity. Several GIS studies indicated that having a dedicated GIS department, influences the development of GIS within an organization (Alrwais and Hilton 2014; Borges and Sahay 2000; Budic 1993; Croswell 1991; Olafsson and Skov-Petersen 2014). Therefore, this study considers the GIS department as an additional dimension to the maturity model. The five dimensions are summarized in Table 2.

System	Functions of the GIS software used, spatial products utilized and the degree of customization applied to the system
Tasks	Extent of integration between GIS and business process and impact on workflow
Users	Extent to which GIS is used organization wide (internal users, external users, departments and management)
Organization	Managerial environment surrounding GIS
GIS Department	Specification of the department responsible for managing GIS

Table 2. Definitions of the Dimensions

Stages

The number of stages in maturity models varies from roughly three stages of maturity in some models to six stages in other models. In describing the design process of developing maturity models, De Burin Freeze, Kaulkarni and Rosemann (2005) argue that "the number of stages may vary from model to model, but what is important is that the final stages are distinct and well-defined, and that there is a logical progression through stages" (De Burin et al. 2005). The authors of a maturity model describing the usage of Enterprise Resource Planning (ERP) systems propose three stages of maturity to describe usage (Holland and Light 2001). Other researchers define three stages (record keeping, analysis and democratization) to describe the use of a multipurpose land information system (MPLIS) post implementation (Tulloch and Epstein 2002). Brodzik outlines three stages (infancy, intermediate and mature) to describe the evolution of enterprise GIS (Brodzik 2004). Roger Tomlinson also uses three levels to define the scope of GIS in organizations as a single purpose project, department level application, or an enterprise system (Tomlison 2007). John O'Looney, a specialist in GIS projects for local government, employs three phases (beginning, intermediate, and advanced) to describe GIS administration (O'Looney 2000). Rebecca Somers, a GIS consultant, again uses the notion of three levels (business tool, data and service resource, or an enterprise) to describe the different organizational models of GIS depending on the role and scope that GIS plays (Somers 1998). Given the support for the notion of three levels to describe GIS components (Brodzik 2004; O'Looney 2000; Somers 1998; Tomlison 2007; Tulloch and Epstein 2002), this study postulates that three stages (exploration, exploitation, and enterprise) would be appropriate to describe the maturity in using GIS.

Exploration: The organization is investigating the benefits of GIS to its activities and the services it offers. It is used primarily to comply with regulations and to produce maps occasionally. Beyond that, development of GIS is led by individual enthusiasts eager to learn the technology and adopt it to their work. A more coordinated development occurs in the form of projects when new needs arise or as a reaction to an event. Recognition of GIS is very low outside the circle of planners and engineers thus skills in using GIS are scarce. The use is not coordinated as departments work in silos with GIS and very few sharing of spatial data occurs. GIS specialists are distributed around the departments (those who perform mapping in the planning, fire, or public works department). In some instances, the GIS could be maintained by an outside contractor all together (outsourced). Only basic functionalities of GIS have been explored. The focus is on digitizing, data collection, and building base maps (framework data). GIS is used more as a data resource for record keeping. On other occasions, GIS is used to replace manually produced paper maps and perform limited measurements (distance, directions, proximity, and buffering). As a result of duplicate data and distribution of GIS professionals over the departments, spatial data reporting is rarely real-time.

Exploitation: The organization has recognized the importance of GIS in improving the performance of obvious departments and process (well-established processes where the need for GIS is evident). GIS is heavily used within these departments and is routine. Other departments (where geography is not a crucial part of their work) are beginning to exploit the functionalities of GIS. Duplication of effort still occurs, as coordination remains low. A GIS coordinator or manager may exist but is usually influenced by a specific department (due to the hierarchy, as the GIS team might be positioned under the IT department for example), which limits the role that GIS can play in organizational development. However, GIS usage by operational management and field workers is widespread and is integrated with a fair number of processes. GIS in this stage acts as a 'Service Bureau' meeting the needs and demands of other departments. But often this results in duplication of effort, and a staff that cannot possibly meet all of the demands of other departments. Slowly, applications are modified to take advantage of GIS. Not all applicable processes are spatially enabled.

Enterprise: The organization has recognized GIS as a strategic asset (mission critical) that provides competitive advantage and is essential to the success of the organization in fulfilling its mandates. GIS is integrated with strategic planning. GIS is used extensively across the organization. Critical mass has been reached and the organization sees the benefit of a multi-purpose enterprise system beneficial to the whole organization. GIS is the glue that connects departments and processes together. Spatial information is used by senior management to make decisions and form policies. There exists a GIS department responsible for managing the spatial data for all the departments (central database and data model) to use and for providing the required services (solutions, applications, changes, and training). Processes are continuously reengineered to take advantage of GIS. Usage and sharing of spatial data is not limited to inside the organization: external usage (individuals and agencies) of GIS exists. Organizational changes are widespread to obtain strategic value of GIS.

Content

Dimensions	Stage 1: Exploration	Stage 2: Exploitation	Stage 3: Enterprise
System **1) GIS functions used** **2) GIS products utilized** **3) GIS Customization**	1) Mapping (overlay, visualization), basic measurement and spatial database 2) Desktop GIS 3) Vendor driven	1) + Spatial and statistical analysis 2) +Online GIS 3) Minimal	1) + 3D, decision modeling, forecasting and monitoring 2) +Mobile GIS 3) Extensive & ongoing

Tasks **1) Core process** **2) Support process** **3) Complexity of the task** **4) Workflow reengineering after GIS**	1) Only in certain established process 2) Minimal 3) Simple (location, structured) 4) Digitize manual process	1) ≈40% core process supported by GIS 2) ≈40% support process supported by GIS 3) Moderate (trends, semi-structured) 4) Moderate changes to take advantage of GIS	1) ≈60% core process supported by GIS 2) ≈60% support process supported by GIS 3) Complex (what if modeling, unstructured) 4) Radical changes as GIS enables new and existing workflows
Users **1) Number of internal users over all employees** **2) Number of departments using GIS over all departments** **3) Extent to which GIS is used at the operational, tactical and strategic level of management** **4) Number of GIS connections (usage agreements) with outside agencies**	1) <20% 2) <20% 3) Operational: Moderate Tactical: Minimal Strategic: None 4) None	1) 20-40% 2) 20-40% 3) Operational: Moderate Tactical: Moderate Strategic: Minimal 4) <3	1) 41% or more 2) 41% or more 3) Operational: High Tactical: High Strategic: Moderate 4) 3 or more
Organization **1) GIS Vision** **2) GIS Strategic Plan** **3) Purpose of use** **4) Pattern of use** **5) GIS awareness** **6) Training** **7) Cooperation/coordination between departments as a result of GIS**	1) To manage spatial data 2) Doesn't exist 3) Inventory 4) Specialized 5) Low 6) For designated employees only 7) Rare	1) To improve efficiency 2) Researching GIS strategic plans 3) + Analysis 4) Routine (embedded in business process) 5) Moderate 6) During implementation mostly 7) Moderate	1) To enhance decision making 2) Formal document exists 3) + Policy making 4) Innovative 5) High (GIS day exists) 6) Ongoing in house and outside 7) High (team work spirit)
GIS Department **1) Structure** **2) Role** **3) Number of staff** **4) Skill set** **5) Management style** **6) Use of consultants**	1) Doesn't exist 2) Not clear 3) <3 4) Cartography and engineering 5) Traditional (order taking help desk approach) 6) To justify initial investments	1) A team within a department 2) Provide basic GIS functionalities 3) 3-7 4) + Web programming 5) Service oriented 6) During implementation	1) Stand alone department 2) Support organization 3) 7 or more 4) + Mobile programming + Business knowledge 5) Customer oriented (on demand solutions) 6) Ongoing and considered important

Given the dimensions outlined, this study mapped these dimensions over the three stages of maturity. Based on the related work discussed earlier, this study extracted relevant benchmark variables to assess and evaluate each dimension. This study integrated the components of GIS usage that were previously dispersed, fragmented, and studied in isolation. The values for each stage over the dimensions were guided by what was described and assessed in the literature. The model is presented in Table 3 and follow a simple logic of evolution from basic and few to advanced and abundant. The model is based on the assumption that the stages build on each other and that the optimal goal of GIS is to be used as an enterprise system to inform decision making.

Research Design

Although earlier maturity models were developed without a consistent process, lately several methods and guidelines for designing maturity models have gained support in academia. De Bruin et al were the first to propose a development method, which has a clear logic and sequence between the phases, does not limit their method to a specific research method, and their method has been used widely. For these reasons, this study followed the De Bruin method in designing the GIS Usage Maturity Model (Table 3) except the last phase as it relates to the long-term management of the model, which is outside the scope of this study.

De Burin Methodology

De Burin et al proposed five phases to be followed in developing a new maturity model. The first phase called 'scope' deals with setting the boundary, focus (general or specific), target and domain of the maturity model. This step is followed by an examination of the literature and comparisons with existing maturity models. Then the purpose of the new maturity model can be better articulated (complement existing maturity models, be applied to a new domain, etc.). Once these steps are completed, stakeholders are identified to assist in designing the new maturity model (De Burin et al. 2005). For this study, the domain is local government and it has a specific focus in GIS maturity. This study has examined the related work and the purpose of this model is to diagnose the maturity of an organization in using GIS 'as-is' and enable "comparative benchmarking" (De Burin et al. 2005). Stakeholders to be involved in the development of this model include local government (cities and municipalities), academics, GIS consultants, and experts within the GIS industry.

The second phase labeled 'design' is concerned with the approach for operationalizing the maturity model. This phase includes the approach of design (top-down or bottom up), assessment method (self-reported or 3rd party), number of stages, stage definition, and components of the model (De Burin et al. 2005). This study has clarified this phase in the section that described the model.

The third phase named 'populate' focuses on how the content of the model (components, sub-components), validation of the content (literature review, expert interviews, delphi technique, nominal group technique, case study, focus groups) and measurement method (survey, case study) will be developed (De Burin et al. 2005). The content of the model has been discussed in previous sections. The validity of the content will be described in the data analysis section.

The fourth phase marked 'test' intends to insure relevance and rigor of the design by examining construct (face and content) and instrument validity, reliability, and generalizability (De Burin et al. 2005). Construct validity for the model has been insured by careful and thorough examination of the literature, expert opinions, and the results from an initial pilot study. Furthermore, the model has been tested on a larger scale across the cities of Southern California.

Expert Opinion

After formulating the model, the study sought expert opinions to confirm support for the model. Emails were sent to 17 individuals (academics involved with GIS in local government, practitioners, and GIS consultants). There were five respondents who provided in-depth feedback regarding the model. The majority of the responses acknowledged the importance of evaluating local government's use of GIS and supported the overall structure of the model. Comments included suggestions for definition of stages, notes about wording, relaxing the values of variables for some stages, suggesting the possibility of needing more stages, need for clarifying variable description, questions about how the model will be measured and by whom, and proposing extra dimensions (data and knowledge management). These opinions were taken into consideration and the model was revised accordingly.

Pilot Study

Following the feedback and validation by experts, the next step was to build the measurement tool (a questionnaire). The literature again provided some initial questions and items. However, for the remainder of the model, new questions needed to be developed. These questions contain straightforward statements reflecting each indicator of the model and seek facts regarding actual overall usage not behavior, opinion, intentions, or individual beliefs. Simply put, a questionnaire was built based on the model description (Table 3).

Once the initial questionnaire was complete, a statistician was consulted to assess the soundness of the instrument, that is, to confirm that the questions were clear and were the correct metrics. The study approached three organizations (city, public agency, and a GIS vendor) and two accepted an interview session. Feedback that was obtained from this pilot study included modification to the phrasing of questions and items, order of listing, addition/deletion of some items, concern about the length of the questionnaire, and revisions to the stage description. The questionnaire was adjusted based on these responses. The questionnaire is composed of five parts. The first section deals with demographics regarding the participant. Section two contains questions regarding the city/municipality. Section three focuses on the history of GIS in the city. Section four contains the questions directly related to the model while section five deals with the value gained from GIS to the city. The questionnaire can be accessed at https://cgu.co1.qualtrics.com/SE/?SID=SV_3sDsXLtz0TywfWZ the questions pertaining to the model begin from part four.

Population

Government has been an early adopter of GIS and hence, it is expected that there will be variations in the use of GIS in government. Local governments in specific, have long-used GIS for planning land use, zooning, taxation, infrastructure management, and emergency planning and thus constitutes a suitable study sample. In an effort to control for the variations that exists among local governments (such as policies and regulations, population, size, geography and terrain, weather, and tourism), the study focused on cities within Southern California. Southern California is divided into 10 counties and includes 235 cities. The study accessed the websites of each of these cities to obtain email addresses of employees thought to be involved with GIS (GIS manager, GIS analyst, IT staff, or planner). The study also obtained the email addresses from a secondary source via the Southern California Association of Governments (SCAG). An invitation email was sent to these individuals and all 235 cities asking them to participate in an online questionnaire. To encourage participation, five amazon gift cards were offered randomly for completed responses. Data collection took place between 16 March 2015 and 26 May 2015.

Data Analysis

The questionnaire was available online and 235 cities were emailed a unique URL to access the questionnaire. 16 cities did not participate; 172 cities started the survey; and 97 cities completed the questionnaire yielding a response rate of 41.3% (incomplete responses were ignored).

To test for reliability of the measurement tool, the study computed Cronbach's alpha for each of the five dimensions. The users and GIS department dimensions had a Cronbach's alpha less than 0.7, the minimum acceptable value for a reliable measure (George and Mallery 2003). After further investigation of these two dimensions, it was found that the number of usage agreements and use of consultants had the least correlations with other indicators in each dimension (less than 0.26 for the correlation coefficient at a very low significance level). These two indicators were removed from the model. Table 4 shows Cronbach's alpha after deletion for each dimension and for all the indicators together. The values are above 0.7 regarding the reliability of the measure.

Element	**Cronbach's alpha**
System dimension	0.74
Tasks dimension	0.85
Users dimension	0.77
Organization dimension	0.81
GIS department dimension	0.71
All indicators together	0.94

Table 4. Reliability test for the model

Confirmatory factor analysis was performed to test the validity of the proposed model. The Chi-square test was 0.000 (closer to zero indicates good fit) and the Comparative Fit Index (CFI) was 0.912 (≥90 indicates fair fit and ≥.95 indicates good fit (Hu & Bentler 1999)), and Root Mean Square Error of Approximation (RMSEA) was 0.070 (≤.08 indicates fair fit and ≤.05 indicates better fit (Hu & Bentler 1999)). All the indicators loaded on the factors higher than 0.70 except for the customization of GIS (0.614) and the number of employees in the GIS department (0.477). The results of the validity test support the model but raise questions regarding including GIS customization and the number of GIS staff in the model due to their low loadings on their dimensions.

"GIS Usage Maturity" was assessed for each respondent city. The maturity calculation follows the traditional method in the literature by taking the average indicator for each dimension then taking the average of all dimensions (Giff and Jackson, 2013). Table 5 shows the maturity break down for each organization for each dimension. A score of 1 indicates stage 1 'exploration', 2 'exploitation', and 3 represent 'enterprise' stage. Columns represent average maturity for each dimension (System, Tasks, Users, Org, Dep), 'CalMatu' represents the calculated usage maturity while 'PerMatu' represents perceived maturity. Each row represents a single organization and the table is divided to three sections for space management. Values in each column range from 0 to 3. Table 5 is ordered from low mature organizations to high maturity organizations based on their usage of GIS.

The average maturity score for the sample is 1.85 meaning that on average, surveyed cities were closer to the exploitation stage of the model. No city was mature on all dimensions nor was a city less mature on all dimensions which is expected as organizations might have strength in some areas but struggle in other areas. However, the model is able to differentiate between more mature organizations and less mature ones as can be seen from the variability of scores. The lowest maturity on the sample was 1 while the highest scored 2.8 out of 3.

System	Tasks	Users	Org	Dep	CalMatu	PerMatu	System	Tasks	Users	Org	Dep	CalMatu	PerMatu	System	Tasks	Users	Org	Dep	CalMatu	PerMatu
1	1	1	1	1	1	1	1.67	1	1.33	1.71	1.6	1.5	1	2.33	1.75	2.33	2.43	2.2	2.2	3
1	1	1	1.29	0.8	1	1	1.67	1.25	2	1.43	1.2	1.5	1	1.67	2.5	2	2.43	2.2	2.2	3
0.67	1	0.67	1.57	1.2	1	1	1	1.75	2	1.29	1.6	1.5	2	2.33	2	2	2.29	2.2	2.2	2
0.67	1	1	1.14	1	1	1	2	1.5	1	1.71	1.4	1.5	1	1.67	2.5	3	2	2	2.2	3
1.33	1	1	1	1	1.1	1	1.33	1.5	2.33	1.57	1.4	1.6	2	2.67	2.25	1.67	1.86	2.4	2.2	2
1.33	1	1	1	1	1.1	1	2	1.5	1.33	1.57	1.4	1.6	1	2	1.75	2.67	2.29	2.2	2.2	2
1.33	1	0.67	1	1.4	1.1	1	1.67	1.25	1.67	1.29	2.2	1.6	3	2.33	2.25	1.67	2.71	2.4	2.3	2
1.33	1	1	1.14	1.2	1.1	1	1.33	1	2	1.86	1.6	1.6	2	2	2.25	2.67	2.57	1.8	2.3	3
1.33	1	1	1.29	1	1.1	1	2	1.25	2	1.57	1.4	1.6	1	2.67	2.5	2	2.71	1.8	2.3	3
1	1	1	1.43	1	1.1	1	2	1.25	1.67	1.71	1.8	1.7	1	2.67	2	2.67	2	2	2.3	2
1.33	1	1	1.29	1.4	1.2	1	1	1.75	2.33	2	1.6	1.7	3	2.67	2	2.67	2	2.2	2.3	3
1.33	1	1.67	1.29	0.8	1.2	1	1.67	1.5	1.67	1.71	2	1.7	2	2.33	2.5	2.67	2.43	1.6	2.3	2
1	1	1	1.43	1.6	1.2	1	1.67	2	2	1.57	1.4	1.7	2	2.67	2	2.33	2.14	2.2	2.3	2
1.67	1	1	1.29	0.8	1.2	1	1.67	2.5	1.67	1.86	0.8	1.7	3	2.33	2.25	2.67	2.29	2.2	2.3	3
1	1	2	1.71	0.8	1.3	2	1.67	1.75	1.67	1.43	2	1.7	2	2.33	1.5	2.67	2.29	2.6	2.3	2
1.33	1	1.33	1.43	1.6	1.3	2	2	2	2.33	1.71	0.8	1.8	2	2.33	2.5	2.33	2.29	2.4	2.4	2
1.33	1	1.67	1.43	1.2	1.3	2	2	1.25	2	2.14	1.6	1.8	2	3	2.25	2.33	2.14	2.4	2.4	2
1.33	1	1	1.43	1.6	1.3	1	2	1.75	1.67	1.14	2.2	1.8	3	2.33	2.5	2.67	2.29	2.2	2.4	2
1.67	1	1.33	1.29	1.4	1.3	1	1.33	2	2.33	1.57	1.6	1.8	3	2.33	2.25	3	2.29	2	2.4	3
1.33	1.25	1.33	1.43	1	1.3	1	2.33	2	1.67	1.43	1.6	1.8	2	2.67	2	2.33	2.29	2.8	2.4	3
1.33	1	1	1.57	1.6	1.3	1	1.33	2	1.67	2.14	1.8	1.8	2	2.33	2.75	2.67	2.14	2.2	2.4	3
1	1.25	1.33	1.14	1.6	1.3	2	2.33	1.5	1.67	1.86	2	1.9	3	2.67	2.5	2.33	2.43	2.6	2.5	3
1.67	1.25	1	1	1.6	1.3	1	2	1.75	2.33	1.86	1.8	1.9	1	2.67	2.75	2.67	2.57	2	2.5	3
1.33	1.25	1	1.29	1.4	1.3	1	2.33	1.5	2	1.57	2	1.9	1	3	2.5	2.67	2	2.2	2.5	2
2	1	1	1.14	1.8	1.4	2	3	1.25	2.33	1.71	1.6	2	3	3	2.5	2	2.14	2.8	2.5	3
1.67	1.75	0.67	1.57	1.2	1.4	2	2.33	2	1.67	1.86	2.2	2	3	2.67	2.5	2.67	2.86	2.4	2.6	3
1.33	1	2.33	1.43	1	1.4	1	2	1.5	2	2	2.4	2	3	3	2.25	2.33	2.57	2.6	2.6	2
1.67	1	1.33	1.29	1.8	1.4	2	2.33	1.75	2.67	2	1.8	2.1	2	3	2.75	3	2.14	2	2.6	2
1	1.5	1.67	1.57	1.6	1.5	2	2	1.5	2.33	2.57	2.2	2.1	3	3	2.75	3	2.29	2.4	2.7	3
1.33	1	2.67	1.57	1	1.5	1	2	1.5	3	1.86	2.2	2.1	3	2.33	3	3	2.29	2.8	2.7	3
1.33	1.75	1.67	1.71	1	1.5	1	2.33	1.75	2	2.29	2.2	2.1	2	3	3	2.67	2.29	2.4	2.7	3
1	1	2	1.71	1.6	1.5	1	2.67	1.75	2.33	2	2.2	2.2	2	3	3	3	2.71	2	2.7	3
														3	3	3	2.86	2.2	2.8	3

Table 5. Maturity matrix

After rounding the values for the computed maturity, 28 organizations are in the exploration stage, 57 are in the exploitation stage, and 12 are in the enterprise stage. These scores indicate that the majority of surveyed organizations have moved beyond basic GIS yet few have reached enterprise GIS. To better understand the results, the study analyzes each dimension according to the stages in table 6.

	System	Task	User	Org	Unit
Exploration	33%	38%	28%	31%	31%
Exploitation	46%	42%	48%	60%	63%
Enterprise	21%	20%	24%	9%	6%

Table 6. Percentages of stages for dimensions

It can be observed that the organizational and GIS unit dimensions have the least percentages in the enterprise stage. The user dimension scored higher in the enterprise stage than all other dimensions. It can also be observed that the majority falls under the exploitation stage in all the dimensions of GIS usage.

32 respondents described their organization as ‘exploration’ (33%), 35 as ‘exploitation’ (36%), and 30 as ‘enterprise’ (31%). To test for the correlation between self-perceived maturity and computed maturity, the study obtained a 0.73 Spearman correlation coefficient (at .001 significance level), and a Wilcoxon rank sum test between the computed maturity score and the perceived maturity was not significant (p-value = 0.4675) which indicates a correspondence between the description of stages and the scoring method, that is, the computed maturity scores reflected to a reasonable degree the self-perceived maturity of the organization. The study used non-parametric tests as the scale is ordinal and thus normal distribution could not be assumed.

Descriptive statistics indicate that years of experience with GIS range from 0 to 40 with an average of 13.6 years. Esri, Inc. GIS technologies are the most widely used - 85% of all respondents. In addition, 71% maintain GIS in-house, 5% access it through the county, 16% through a contractor or consultant firm, 1% share with a neighboring city, and about 7% have it mixed (in-house and outsourced). These numbers indicate that there is reasonable variety among the cities in how they handle and manage GIS and thus indicate that it is a suitable sample for studying GIS usage.

Basic GIS functions are heavily used (map production 97% and spatial databases 56%) while more advanced functions are substantially lower (GIS for prediction and forecasting is used in only 16% of the respondent cities while decision modeling is at 24%). The same pattern persists and is even clearer when examining the GIS products utilized (86% for basic GIS but only 4% for advanced spatial analytics). Average number of applications is 15.3 out of 54 listed applications. For city processes, land use planning, zoning and districting GIS is used by 91% of the respondents while GIS in the taxation process (property assessment) is used by only 12%. This is reflected by the fact that planning and public work departments remain the largest group using GIS at 92% while the finance and community service departments was used by only 38% of the responding organizations. It seems that GIS is still at its traditional place and this could be partially explained by the fact that 37% of the surveyed organizations do not use consultants on GIS projects, which might limit ‘out of the box thinking’ and where GIS can assist and be of value to the organization.

When examining small organizations (characterized by population, budget and city staff), usage is low. In fact, none of the small organizations in the sample have considered themselves to be in the enterprise stage. This might be due to a lack of a GIS unit, low GIS training, low awareness about the potential of GIS, or insufficient resources (staff, time, and funding). On the other hand, this does not suppose that large cities will automatically be at the enterprise stage. In fact, many large cities in the sample did not reach the enterprise stage of the maturity model.

Results show that the model is reliable (after excluding usage agreements and use of consultants), valid (after excluding customization of GIS and the number of employees in the GIS department) and correlates well with perceived usage maturity. Adding to the statistical support, positive feedback from experts and practitioners contacted, the proposed model does seem valid.

Conclusion

A major goal in e-government initiatives is having an online presence, which caters more to serving its citizens and the general public. GIS on the other hand, is a technology with the potential to transform mainstream local governmental duties. However, this potential cannot be attained without first satisfying certain levels of usage of GIS. Few GIS maturity models have been developed and empirically validated, and as such, a measurement tool is missing regarding the dimensions of GIS usage. In this study, the literature was reviewed regarding system usage, maturity models, and GIS studies to construct a new GIS Usage Maturity Model that is focused on evaluating local government usage of GIS at the organizational level.

The model was validated with academics and experts, pilot tested with two organizations, and then tested with 97 Southern California local governments. The model demonstrates variability among those governments over the three model stages, and provides support for the model. Reliability and validity tests performed also support the proposed model.

Regarding the research questions, this study has demonstrated that the system, tasks, users, organization, and GIS department are necessary dimensions in studying GIS usage at the organizational level of local government. The content of the model and measurement tool (questionnaire) have been provided.

A majority of local governments are in the exploitation stage regarding their usage of GIS. However, using GIS for complex and unstructured decisions is low (only 20% use GIS in complex tasks, only 20% experienced radical changes to workflow of processes as a result of GIS, only 22% have a vision for GIS to be used at decision making, and only 12% have plans for the growth of GIS). What seems to be lacking is the strategic use of GIS by senior management regarding high-impact decisions.

It should be noted that the organizations in the sample did not always follow the characteristics of each stage; but rather fluctuated between the dimensions being more mature in one dimension than the other. This is expected, as the model, as it is conceptually conceived, describes the ideal arrangement for each stage. The proposed model provides a road map for governments to evaluate their current practices and plan for the development route. The model provides a first step in this area to measure GIS usage organization-wide and provides a foundation for other researcher to build upon. The model applies only for organizations currently using GIS thus a pre-exploration stage could exist (GIS adoption decision and related activities) but is outside the scope of this work.

In future work, we will examine the relationship between GIS usage maturity and GIS impact (value). The goal is to determine if maturity has translated into actual business value and if certain stages are associated with specific GIS value.

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