An Organizational Perspective On GIS Payoffs for the Public Sector: Is Usage the Missing Link?

Full Paper

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Abstract

GIS offers a unique way of layering spatial data, and its related tabular data, that can be visualized through a single map. This feature has made GIS attractive for governments, and especially local governments, as they work with such data on daily basis. Many local governments are currently using GIS and are planning to expand their usage; many are expected to follow in kind. Now is the time to ask the question, “What benefits have the public sector gained from GIS?” This study seeks to answer this question and investigates the role of GIS usage in determining GIS value at the organizational level. A survey was carried out with Southern California local governments in an effort to understand the relationship between the level of GIS usage and gained value of GIS. Results suggest that increasing actual GIS usage leads to an increase in GIS value. Results further show that efficiency and effectiveness benefits of GIS are mostly realized, however, societal benefits of GIS are small.

Keywords


Introduction

The influx of data collection is so rapid and ever increasing to the extent that we might be ‘drowning in data’. In the era of big data and data analytics, IBM claims that 2.5 quintillion (a billion times a billion) bytes of data are generated each day (IBM, 2013). Part of this generated data is geo-coded (spatially referenced). Images, text, video and mobile phones can all be geographically tagged. Even recent Unmanned Aerial Systems (UAS) or drone technology collects and processes spatial data. As the availability of spatial datasets proliferates, demand for maps to visualize these various data types is rising.

Cities all over the world are facing enormous challenges. An increase in urban population means more pressure on existing infrastructure (roads, sidewalks, parking spaces, sewers, housing, safety, and food) and more pollution. What further complicates the situation is that cities still exhibit budget constraints, political gridlock, green infrastructure demand from the younger generation, vision towards smarter cities, mandates for more transparency (e.g., body cameras for police officers), public participation, and the birth of a new economy (the ‘sharing economy’). Consequently, cities have to adapt to accommodate these changes and do more with less. Since much of local government data is spatially linked and most of these challenges are of a geographical nature, GIS has a central role to play in fulfilling or guiding the transition into solutions to these challenges. However, is local government’s GIS ready to confront these challenges?

The global GIS industry generates between $150 to $270 billion dollars of revenue yearly (Oxera, 2013). For the 2015 budget, the department of commerce, defense, health and human services, homeland
security, interior and transportation alone estimated that they would spend about $1.3 billion on critical IT investments closely related to geospatial technology (Government Accountability Office, 2015). The GIS industry is growing, and spending on GIS is increasing from both the public and private sectors. One approach to understanding the developments occurring in ‘GIS world’ is to evaluate current practices in the use of technology organization-wide and simultaneously search for its impact over the whole organization and beyond. The need for GIS is more compelling than in the past. Nonetheless, numerous studies have raised concerns and doubts about GIS value beyond basic mapping and suggested underutilization of GIS capability (Gudes, Mullan and Weeramanthri 2015; French and Wiggins 1990; MacDonald and Radcliffe 1997; Weir and Bangs, 2007; Ye, Brown and Harding 2014). In addition, reported gains about GIS impact and value are mixed and contradictory (Akingbade, Navarra and Georgiadou 2009). Also, studies that looked into GIS value have not considered the role of usage or examined the value comprehensively at the organizational level.

Literature Review

Business Value of IT

This stream of IS research seeks to examine the association between IT investments and firm performance. Melville et al. (2004) defines business value of IT as “the organizational performance impacts of IT at both the intermediate process level and the organization-wide level, and comprising both efficiency impacts and competitive impact” (Schryen, 2013). Research has accumulated a critical mass of empirical studies to assert a causal link between IT resources and some measure of firm performance (Daulatkar and Sangle 2015; Kohli and Grover 2008; Schryen, 2013) but effect size varies. Schryen (2013) calls for disaggregating IT investments to understand how specific systems impact firm performance and to be able to compare results of empirical studies. There is a growing interest in the literature to measure the extent of IT use and correlate that with firm performance. In fact, Hadaya et al. (2012) assert that IT investments alone do not generate value and that the use of IT is a better predictor of firm benefits. Moreover, Zhu et al. (2005) state that the business value of IT stems from the degree of IT use in core competencies of the firm’s value cycle and that “the greater the usage, the more likely the firm is to develop unique capabilities from its core IT infrastructure” (Mishra et al., 2007). Kumar (2004) also argues for considering system usage in BVOIT as he explains “it is important to consider IT usage in measuring IT value instead of using the dollar value of investments, since value depends on usage of IT and not on investment alone”. Thus, it is legitimate to include system usage in the cycle of BVOIT research.

Business Value of GIS

Business value of GIS, when considered is mostly derived by financial measures (such as return on investment) assuming an organization is profit driven. A common method to evaluate the economic outcome of a business investment (project, program, or policy) is through cost-benefit analysis (CBA) (Worrall, 1994). This analysis considers the ratio of benefits to costs and regards the investment a success if the ratio is greater than one (Nedovic-Budic, 1999). This type of analysis has been applied numerously to evaluate GIS projects but some researchers have disputed the employment of CBA to evaluate GIS projects (Dickinson and Calkins 1988; Nedovic-Budic, 1999; Wilcox, 1990) mainly due to the difficulty of quantifying intangible benefits. Additionally, CBA and similar tools, focus on the investment decision and business case for the private sector and as such, fall short as a comprehensive methodology for the evaluation of a system in the public sector that is not necessarily profit driven.

Akingbade et al. (2009) reviewed the literature on GIS impact from 1998-2008, which yielded 38 articles from different disciplines. They claim that a CBA would be inadequate to measure GIS value as it captures only the tangible benefits of GIS and thus they draw upon the related work of Clap et al. (1989), Danziger and Anderson (2002) and Tulloch and Epstein (2002) to propose a taxonomy of GIS impact. Akingbade et al. (2009) categorize GIS value into gains in efficiency, effectiveness, and societal well-being. It was found that 56% of the literature examined the efficiency impact of GIS (45% positive impact, 18% negative, 32% mixed), 39% examined the effectiveness benefits (26% positive, 18% negative, 18% mixed) and only 5% of the literature paid attention to social impact of GIS (3% positive, 5% negative, 3% mixed). Akingbade et al. (2009) corroborates the work of Nedovic-Budic (1999) that the results of societal impact of GIS are
inconclusive and requires more investigation. The societal impact of GIS is an important category as the ultimate goal of GIS is to benefit society (Nedovic-Budic 1999) and as such, public organizations may have different goals than private corporations for which this category might not apply. Akingbade et al. (2009) define efficiency as a “ratio of outputs to inputs ... expressed as cost savings, cost avoidance or productivity gains (Nedovic-Budic 1999)” effectiveness as “improvement in the performance of an organization’s fundamental duties (Tulloch and Epstein 2002)” societal well-bring as “how GIS technology has transformed society and its way of dealing with human problems” (Akingbade et al., 2009). Akingbade et al. (2009) work is more recent, makes use of the related literature, includes societal benefits, and measures GIS value (including tangible and intangible benefits of GIS) objectively (not based on opinions or preferences of the user rather on the declaration if the indicator under question has been attained or not) over the organizational level, and accordingly will be used in this study as a framework for measuring GIS value.

From System Usage to Business Value

System usage is a core construct that has been central in the domain of IS success, IS implementation, IS decision performance, technology acceptance, and system performance (Burton-Jones and Straub 2006). System usage is a “pivotal construct in the system-to-value chain that links upstream research on the causes of system success with downstream research on the organizational impacts of information technology” (Doll and Torkzadeh 1998). Devaraj and Kohli (2003) investigated directly the relationship between actual system usage (DSS system) and hospital performance. They found that “technology usage was positively and significantly associated with measures of hospital revenue and quality, and this effect occurred after time lags”. Ruivo et al. (2012) used the ideas of Devaraj and Kohli (2003) and found a positive link between Enterprise Resource Planning (ERP) use and ERP value. Also in the mobile commerce domain, Picoto et al. (2014) found that “mobile business usage has a positive and significant relationship with mobile business value”. Moreover, Tu (2001) explored the role of ERP usage from an organizational level on firm performance and found that “firms with high levels of IS usage generally have better manufacturing performance”. In the GIS domain, many studies that explored the effect of spatial information presentation on the performance of the decision making process and in problem solving have found that GIS improves spatial decision making in terms of duration (time to arrive at a decision) and quality (accuracy of a decision) especially for more complex and unstructured decisions (Smelcer and Carmel, 1997; Dennis and Carte, 1998; Mennecke et al., 2000; Erskine and Gregg, 2013). There are reasons to conclude therefore, that the link between GIS usage and GIS value is probable and deserves investigation.

Research Model

This study employs the GIS usage maturity model of Alrwais et al. (2015) to test the relationship between GIS maturity stages and the three categories of GIS value. The research model is depicted in Figure 1. Many studies have documented the positive relationship between system usage and some aspect of business value (Devaraj and Kohli 2003; Kumar, 2004; Picoto et al., 2014; Ruivo et al., 2012; Tu, 2001; Zhu et al., 2005). In the GIS domain, the relationship between GIS usage and GIS impact has also been documented (Calkins and Obermeyer 1991; Eldrandaly et al., 2015; Joffe, 2003; Mennecke el al., 2000;). Thus, this study has a set of propositions:

P1.1 Higher levels of GIS usage maturity will be associated with higher levels of GIS value.

P1.2 Exploration stage is positively related to efficiency gains but not related to effectiveness or societal well-being.

P1.3 Exploitation stage is positively related to efficiency and effectiveness gains but not related to societal well-being.

P1.4 Enterprise stage is positively related to efficiency, effectiveness and societal well-being gains.

Some GIS studies have found a positive relationship between characteristics of a city (e.g., size, budget, years of experience with GIS) and the state of GIS development (Colijn and Huyckburg 2000; Convery and Ives-Dewey 2008; French and Wiggins 1990; Johnson, 2013; Kun, 2014; Nedovic-Budic, 1993; Olafsson and Skov-Petersen 2014) in that larger organizations are more likely to have a well developed
and functioning GIS. Other studies have stressed the importance of a ‘GIS champion’ in GIS development and success (Borges and Sahay 2000; Convery and Ives-Dewey 2008; Onsrud and Pinto 1993; Nasirin and Birks 1998). Thus,

P2. City characteristics (budget, population, number of employees, city age, county, GIS champion and years with GIS) control the relationship between GIS maturity and GIS value.

Methodology

A questionnaire was developed to measure GIS usage and GIS impact, which has been discussed in Alrwais et al. (2015). In order to test the research propositions, a large-scale survey was conducted. All 235 Southern California local governments (cities and municipalities) were sent an invitation email to participate in the study. The unit of analysis is a single city. The target respondents were GIS managers or GIS staff. The questionnaire was organized into five sections and included 51 questions. The first section included demographic information regarding the respondents to insure that the person filling out the survey on behalf of the city was experienced in GIS. The second section included questions about the city in general while the third section included specific information regarding GIS history in the city. The fourth section was devoted entirely to measuring GIS usage based on the maturity model using 28 questions. The fifth section had questions concerning GIS benefits to the city using 21 questions. The maturity score ranged from 0-3 while the GIS value ranged from -42 to +42 (21 questions multiplied by a 4 point Likert scale).

Operationalization

The measurement for GIS maturity was discussed in Alrwais et al. (2015) and included 24 indicators to measure the five dimensions of GIS maturity. For GIS value, the Akingbade et al. (2009) framework was used (Table 1) and was slightly modified to fit the public sector domain. Respondents were asked to indicate whether they agreed or disagreed with each value indicator if the benefits had been realized in their city as a result of using GIS. A four-point Likert scale was used (strongly disagree, disagree, agree, strongly agree) which had no middle point (neutral). This strategy was chosen to force respondents to think deeply and choose whether the indicator under question had been achieved or not.
Table 1. Taxonomy of GIS impact (derived from Akingbade et al., 2009)

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
<th>Indicators</th>
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| Efficiency          | The degree to which GIS operates with minimum (waste, duplication and expenditure of resources) or with the same level of inputs but provides greater output (productivity). | 1. Better allocation of resources (labor, space, material and capital)  
2. Cost (savings or avoidance)  
3. Increased productivity (automation & simplicity which translates into greater output with less or the same resources)  
4. Better spatial data management capability (acquisition, storage, retrieval, coverage, completeness, accuracy, availability, access and dissemination)  
5. Time-saving |
| Effectiveness        | The extent to which GIS has contributed to the satisfaction of information needs, in adequate quantity and quality of data and decision-making process. GIS enhances performance as well as enabling many business processes that are not possible without GIS. | 1. Adequacy of service relative to the need (satisfies information needs with expected quality)  
2. Improved planning, coordination and cooperation  
3. Improved products and services  
4. Increased job satisfaction (internal users satisfied with the technology and decisions made based on it)  
5. Better conflict resolution (as a result of information)  
6. Support for more explicit articulation of decisions (improved decision making, better decisions than without GIS)  
7. More responsive to the needs of citizens |
| Societal well-being  | The degree to which GIS helps in the realization of collective goals of a society or impact of GIS on broad societal objectives such as “individual integrity, social justice, distribution of wealth and fulfillment of human aspirations”. | 1. Citizen-public sector interactions (Public participation and citizen empowerment)  
2. Economic benefits (increased revenue for example accurate taxation or fraud detection)  
3. Enhancement of principles of a democratic society, for example, freedom from constraints such as corruption (better transparency)  
4. Improved standard of health and safety  
5. Protection of legal rights, such as privacy (surveillance and confidentiality)  
6. Social justice: fair treatment and a just share of benefits, for example equal availability of information to citizens when needed and equal ease of access (equity) |

Results

The questionnaire was sent to 235 cities within the 10 counties of Southern California; 96 respondents (cities) completed all questions. Reliability tests for the maturity model were reported in Alrwais et al. (2015) in which 20 of the 24 indicators were found to be reliable. For GIS value, Cronbach's alpha was used as the reliability test and the value for efficiency category was 0.92, effectiveness scored 0.94, societal well-being 0.91, and the reliability for all indicators of GIS value was at 0.96. All Cronbach's alpha scores were above 0.7, which provides support that the measure is highly reliable.

Figure 2 shows the sample responses to the indicators of GIS value. There is agreement about efficiency and effectiveness gains but societal benefits of GIS are rarely realized. It is interesting that there is no consensus about GIS impact on improving health, safety, and enhancing economic value although GIS vendors promise significant advances in those areas. Most organizations surveyed expressed positive sentiments regarding the impact of GIS (on average, 73% agreed that the question regarding GIS value has been realized in their city). Most agreed that the impact of GIS was its ability to improve city planning, enhance spatial data management, increase productivity, time savings, higher information quality, and provide better service to the public.
Figure 2. The realized impact of GIS

These payoffs are internal to the organization. On the other hand, the least realized value of GIS was its contribution to social justice, protecting legal rights, enhancing democracy, economic value, improving standards of health and safety, and increasing public engagement. These benefits are external to city management. Since GIS use is mostly internal, the value of GIS is more visible internally. There is a dichotomous understanding regarding the impact of GIS in increasing the economic value and revenue of the city (50% agree, 50% disagree) despite the fact that there is almost a consensus on GIS ability to save costs (89% agree). This can be explained by the fact that GIS is used to improve existing workflows and way of doing business, yet it is not used in innovative and creative ways to bring new revenues or radically improve existing processes. Cities are not aware, or educated about, exemplar success stories of GIS use. In terms of GIS ability to improve the decision making process, 85% agree but the remaining 15% is worrying and deserves attention as to why GIS is failing to provide its fundamental duties here (for example it could be that decision makers do not trust GIS analyses and rely on their experience).

When aggregating these GIS value indicators to the category level, this research found that 65% obtained all efficiency gains, 57% realized all effectiveness gains, while only 21% reached all societal well-being gains. It can be also observed that GIS value is cumulative, meaning that effectiveness gains occur after efficiency (in 48 of the 55 cases of the sample), and societal well-being occur after effectiveness gains (in all 20 cases of the sample). When comparing this (actual) with the category of perceived GIS value, 26% perceived efficiency gains, 63% reported effectiveness gains, and only 11% stated that GIS made contributions to societal well-being. Consistent with previous research (Pickles, 1995), this study found that using GIS to achieve societal well-being, or equitable benefits and goals, is rare and difficult (only 21% indicated this from the measurement tool and 11% from perceived value). One possibility for this is that GIS for the most part, is not used to solve the big problems that face society but rather is limited to narrowly defined problems.
To test proposition 1.1, the correlation between the maturity score and total GIS value is computed. The Spearman correlation coefficient between these two variables is 0.72 (significant at the < 0.001 level), which indicates a strong relationship. To examine the propositions concerning the stages of GIS usage and categories of GIS value, the answer for the value questions has been aggregated to either agree or disagree. There were 29 organizations in the exploration stage; of those 7 have attained efficiency gains (against 22), 6 also obtained effectiveness gains (against 23) and two have claimed that they reached the societal well-being gains (against 27). These results suggest that proposition 1.2 is not supported (because only few obtained efficiency value and more have effectiveness value which contradicts the proposition). There were 57 organizations in the exploitation stage; of which 45 reported efficiency gains (against 12), 39 reported effectiveness gains (against 18) and 11 reached societal well-being gains (against 46). The results suggest that proposition 1.3 is partially supported (because some reached societal gains which isn’t inline with the proposition). There were 10 organizations that reached the enterprise stage all of whom reported efficiency and effectiveness gains and 7 reported societal well-being gains. The results suggest that proposition 1.4 is supported.

To test the second proposition that external environment characteristics control the relationship between GIS usage and GIS value, Multiple Regression was used to explore these relationships. Regression results are shown in Table 2 in which GIS maturity and control variables were regressed on GIS value. Dummy variables were used to represent the categories of budget, population, city employees, GIS champion, GIS form, and county. In total, there were 28 independent variables; only the significant variables are shown in Table 2 due to space limitation.

<table>
<thead>
<tr>
<th>R Squared</th>
<th>Adjusted R Squared</th>
<th>Residual standard error</th>
<th>Degrees of freedom</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>.65</td>
<td>.52</td>
<td>11.57</td>
<td>68</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Coefficients</th>
<th>B</th>
<th>Std. Error</th>
<th>t value</th>
<th>Sig</th>
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<tr>
<td>Intercept</td>
<td>-40.9</td>
<td>7.3</td>
<td>-5.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>GIS Usage Maturity</td>
<td>24.1</td>
<td>3.5</td>
<td>6.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Is GIS Supported In-House?</td>
<td>10.1</td>
<td>3.9</td>
<td>2.6</td>
<td>0.012</td>
</tr>
<tr>
<td>Is Orange County?</td>
<td>10.5</td>
<td>5.1</td>
<td>2.0</td>
<td>0.044</td>
</tr>
</tbody>
</table>

**Table 2. Regression Summary**

The Regression model explains about 50% of the variability in GIS value of which, GIS maturity is a large part. Organizations that have GIS support in house (compared to those that outsource it or share it with a county or neighboring cities) tend to gain more value out of GIS. Also, cities in Orange County (compared to the other 9 counties) tended to gain more value out of GIS. The other variables did not affect the relationship between GIS usage and value and thus Proposition 2 is not supported. In fact, when the control variables entered the Regression model alone without the maturity score, they accounted for only 20% of the variability in GIS value compared to 52% when maturity is added suggesting that maturity substantially explains GIS value better.

At the end of the questionnaire, respondents were asked to add any additional comments regarding GIS usage or GIS benefits in their cities. An interesting theme that emerged from their responses was the obstacles or barriers to GIS usage in small cities (defined within SoCal as cities with a budget less than 25 million, population less than 49,000 and less than 100 workers and employees). Respondents cited shortage of staff and lack of time (time to grow GIS by adding data and performing analysis) as important hurdles to GIS growth. The reality is that users of GIS come from different fields and often need to be
retrained to use GIS along with their other daily duties. Another issue that was discussed was that without having a dedicated GIS department in a city where GIS staff can focus only on growing their GIS capabilities, GIS is peripheral, and in a ‘no growth’ mode. Another obstacle cited numerous was lack of funding (to invest in the technology, hire GIS staff, or GIS consultants) and resources for GIS projects. Without expanding the user-base of GIS, it is difficult to convince top management to accept the cost of GIS. Cities still suffer from budget constraints that make investments in technology challenging, however, respondents reported that they had devised alternative methods to fund GIS. Some cities rely on the County GIS for most of their needs (although some counties have reduced their GIS staff and have also decided that tools like Google Earth were sufficient for all their GIS tasks), others partner with local non-profit agencies (associations, universities, students, and research centers), some utilize cloud-based GIS subscriptions and some have been trying Free and Open Source Software GIS and remote sensing platforms. Some cities seem optimistic about GIS and have plans for growth (in terms of data, applications, and users) while others have given up due to cost issues. It also seems that a portion of the cities are still building their GIS capabilities (digitizing, geocoding, and automating paper records). Some cities still rely on the heroic work of only one individual to maintain the entire GIS system.

Other respondents focused on the positive side of GIS and shared their success stories. Respondents emphasized the role of GIS information (especially when accurate and up to date) in supporting decision-making. Respondents also mentioned the value of providing GIS to non-IT personnel who are able to conduct their own analyses. Benefits even extend to the public in the form of online GIS portals offering various city maps, GIS data, and mapped events (e.g., police calls, property information, local business, and demographic information). Other cities shared their accomplishments and reported that GIS has improved the quality of life in their cities by supporting the city’s goals of better management through more accurate information.

Conclusion

This study attempted to objectively quantify GIS benefits from the organizational level and to investigate its relationship to GIS usage. This study also provided an operationalization of Akingbade et al. (2009) categories of GIS value, which considers the societal implications of GIS that have been often ignored. This work has also corroborated the link between actual system use and system value that is critical to understanding the business value of IT. Consistent with other research in ERP (Tu, 2001; Ruivo et al., 2012), DSS (Kohli et al., 2003) and e-business (Zhu and Kraemer 2005), this study found a significantly positive relationship between GIS maturity and GIS value. The more an organization expands its usage of GIS, the more value they gain. However, the details, order, and temporal occurrence of a specific GIS value associated with a certain increase in GIS maturity need further investigation and research. The overall relationship is positive, but it seems valid to assume that there are other variables that moderate this relationship. These variables could be environmental (e.g., political stability, community pressure, crime rate, household income) or organizational (e.g., perceived relative advantage of GIS, organizational complexity, business process agility, decision maker’s mind set and preferences, and organizational fit) and deserve further investigation.

Contrary to previous research, this study did not find any significant effect for the existence of a GIS champion, city size, or GIS experience on the relationship between GIS usage and GIS value. Measured control variables didn’t better explain the relationship meaning that it is only the degree of GIS usage (extent, breadth, depth, features, users and support) that affects GIS value. Content analysis revealed funding, shortage of skilled GIS staff, and time constraints as barriers to GIS usage in small cities.

Only 21% of the sample claimed that GIS helped in fulfilling the societal (or equity) goals, which could be lower in other states. Looking forward, an investigation could be performed (e.g., case studies, action research) to examine and understand why the societal impact of GIS is difficult to occur and to propose strategies to increase the societal benefits that GIS can enable. Future research could think about new objective measures of GIS value for local government that don’t rely on self-reporting (e.g., number of daily visitors to city GIS website, number of mobile GIS applications, citizen satisfaction indicators or local economy analysis) and reexamine the link with GIS usage maturity. Future research could also test the linkage between GIS usage and GIS value on a cross-state sample to see if the results can be generalized outside Southern California.
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