

December 2006

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Recommended Citation

Pick, James, "A Case-Study Analysis of Costs and Benefits of Geographic Information Systems: Relationships to Firm Size and Strategy" (2006). *AMCIS 2006 Proceedings*. 207.
<http://aisel.aisnet.org/amcis2006/207>

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A Case-Study Analysis of Costs and Benefits of Geographic Information Systems: Relationships to Firm Size and Strategy

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ABSTRACT

Costs and benefits (C/B) of geographic information systems (GIS), methods of spatial C/B, and relationships of GIS costs and benefits to firm size and spatial strategic level are analyzed through a multi-firm case study analysis. Managers responsible for GIS in fourteen U.S.-based firms were interviewed about their company's spatial applications, costs and benefits, spatial strategic level, and management and planning of spatial technologies and GIS. The findings indicate that large firms tend to realize large benefits from GIS and have formal C/B methods. Medium and small firms do not utilize formal C/B methods, and yet report large benefits from GIS. For large firms, the use of cost-benefit methods is associated with higher spatial strategic levels. Findings are compared to the literature on cost-benefit analysis for GIS and spatial technologies.

Keywords

Costs, benefits, cost-benefit methods, geographic information systems, strategic level,

INTRODUCTION

Spatial technologies and geographic information systems (GIS) grew up in government (Longley et al., 2005), but have moved rapidly in recent years into the business sector. As they expand in business, it is useful to examine what are the costs and benefits (C/B) of geographic information systems, how they are evaluated, and what are the relationships of spatial C/B to company size and spatial strategic level. This paper presents the findings from an exploratory case-study analysis of fourteen U.S.-based firms, referring to a sparse literature on cost-benefit analysis for spatial technologies.

A geographic information system is defined as a system that accesses spatial and attribute information, analyzes it, and can produce outputs with mapping and visual displays (Pick, 2004). The trend for spatial technologies in business has been to extend them from traditional GIS systems to enterprise-wide systems that run on web-based architectures (Maguire, 2005; Sonnen and Morris, 2005). A traditional GIS system refers to powerful desktops or client-servers running GIS commercial software. The enterprise-wide systems tend to run under spatial web services architecture.

Cost-benefit analysis methods have been developed for spatial systems (Obermeyer, 1999; Tomlinson, 2003). These studies provide detailed categories for costs and benefits, allocate them into tangible and intangible categories, and examine the steps in spatial cost-benefit analysis. The best-known methods are break-even analysis, baseline cost-comparison chart, and net present value (NPV). Net present value is a weighted average of the costs and benefits discounted over time. One study indicated cost-benefit analyses for information systems are based on four factors: statement of purpose; time simultaneity i.e. retrospective, current, or prospective; scope; and criterion, i.e. how costs and benefits are compared (King and Schrems, 1978). The value of information has been assessed in a body of literature which indicates that IT investment may or may not be productive and beneficial (for example Brynjolfsson, 1993; Lucas, 1999). The benefits depend on economic factors of productivity and can be assessed through frameworks of normative value, realistic value, and perceived value (Ahituv, 1989; Ragowsky et al., 2000).

A few studies have emphasized the strategic aspects of business spatial uses. The framework of Ghosal (1987), useful in understanding IT strategy, was extended to GIS in business (Murphy 1996). Ghosal pointed to three areas of strategic goals: efficiency in current operations; managing risks; and learning, innovating, and adapting.

OBJECTIVES AND RESEARCH QUESTION

The objective of this research is the following: to examine the costs and benefits of GIS and spatial technologies, as reported by 14 case study firms and to assess whether the use of cost-benefit formal methods or the presence of strong benefits are associated with size and strategic level of GIS in the firm.

The paper's Research Questions is as follows:

1. What are the important costs and benefits of GIS for the case study sample of fourteen firms.
2. Do large firms have more use of formalized methods of cost-benefit analysis than medium and small-sized ones?
3. Are the uses of cost-benefit analysis methods associated with high strategic value of GIS?
4. Does the presence of full benefits (productivity gains, performance gains, and improved value) correspond to a high strategic level of GIS.

METHODOLOGY

The methodology for this research is case study (Yin 1993, Yin 1994). The case study strategy consists of definition of the study focus, framework construction, interviews, data collection, and case analysis. Case study investigation often has small sample sizes. The present case study sample was determined by selecting fourteen organizations, in twelve different industries that are known to utilize GIS (see Table 1). The sample of firms is not randomly chosen, but a convenience sample. Five of the industries were ones with high spatial technology use (oil and gas, utilities, retail, environmental services, and transportation) and seven were ones with moderate use (banking, health care, marketing/advertising, newspapers, publishing, consulting, and consumer services). The firms were selected to have different size categories (7 large, 4 medium, 3 small), ownership structures (4 are private, 10 public), and corporate structures. The range of firms is broad in order to encompass a variety of spatial and strategic factors and to demonstrate a range of firms. For each firm, the protocol is to interview the manager or executive responsible for spatial technologies. Interviews, which lasted one hour and 15 minutes, utilized a standard interview protocol and a set of 31 questions covering the areas of applications and uses, support for business decisions, costs and benefits, and competitive advantage. The protocol called for answers to all 31 questions, but was semi-structured in allowing closely-related questions and responses if time permitted. Responses were transcribed in writing and tape recorded, if permission to record was granted. The transcripts were sent to the interviewees for factual corrections. Secondary materials on spatial technologies in the firms were requested, and provided by most firms. They consisted of company reports, powerpoint presentations, internal writeups, articles, and web postings. In addition, secondary business materials were obtained from company websites and standard business information services.

Name or description	Industry	Size
Global Integrated Oil (description)	Oil and Gas	large
URS	Environmental Services	large
Large Credit Bank (description)	Banking	large
Rand McNally	Publishing	large
Southern Company	Utilities	large
Sears Roebuck	Retail	large
Kaiser Permanente	Health Care	large
Bay State Health	Health Care	medium
Lamar Advertising Company	Marketing/Advertising	medium
Arizona Republic	Newspapers	medium
Western Exterminator	Environmental Services	medium
Engineering Systems	Consulting	small
Mapistics	Health Care	small
Motion-Based Technologies	Consumer Services	small

Table 1. Sample of Firms for Case Studies

FIINDINGS OF CASE STUDY ANALYSIS

This section summarizes the uses of GIS and detailed cost-benefit findings for the fourteen companies. The next section consolidates the cost-benefit results and addresses the research questions.

Case Study Findings for Large Firms

Global Integrated Oil. GIO is a global integrated oil giant, with over 50,000 employees, more than \$100 billion in revenues, and business conducted in 180 nations. Spatial technologies are applied enterprise-wide, including in exploration, transportation and storage, refining, environment, marketing, supply chain, and support, and strategic planning. Strategic planning includes spatial analysis of global new ventures and merger proximities of production facilities and office locations.

The biggest cost is in the data input to GIS. The largest losses have occurred in managing the data and meta-data once they have been entered. The next largest cost factor is hiring and retaining very trained and experienced GIS staff. The benefits to productivity are from the ease in bringing multiple data types together, allowing for quick map viewing. The productivity gain comes from the reduction in user time for data searching and increased time for interpretation and analysis. In a conceptual study, it was pointed out that although coordination costs of GIS with other technologies may be high, but there are benefits over the long term (Pick, 2005). Performance gains were present but not able to be converted to dollars due to the complexity of the activities of a giant firm. For instance, the performance gain from avoiding drilling in the wrong location cannot be determined tangibly.

URS. URS is the world's largest integrated engineering design services company of over \$3 billion annual revenues with a global reach. It provides services in systems engineering, planning and design, construction management, transportation operations and maintenance, environmental, water and waste, homeland security, logistics and defense systems. GIS is applied in environment, resource management, general planning, infrastructure, and automated water and sewer.

Costs are conventional ones of people, software, and hardware, while benefits are the quality of output, efficiency of spatial analysis, and ready access to GIS maps. However, the cost-benefit methods are crude, consisting of simple tables of tradeoffs. The GIS manager pointed to a sharp disparity in client perceptions of costs and benefits – initial clients registered sharp surprise at high costs, whereas experienced decision-makers were convinced of net benefits and didn't need a C/B study. There are perceived gains in productivity, performance, and firm value. An example in productivity is the very quick access to great aerial photography and satellite data, often within a few minutes, that meshes precisely with very accurate government urban and environmental data.

Large Credit Bank. This very large bank has had a monoline product line in the credit card area. Recently, it acquired several medium-sized regional consumer banks. Important initial applications are site location, real estate evaluation, and marketing for the acquisitions, plus planning of the corporate campus. The acquired consumer banks are in competitive markets, and the siting of their existing branch locations needs to be evaluated, new sites explored, and geodemographics needs to be performed.

There are low data, hardware and software costs, and people costs involve partial time of some managers and data-base people. GIS provided the benefits of useful analyses of site and location, but are restrained by legacy systems that dominate for wider applications. Because of the parent bank's resistance to GIS, little has so far be implemented, and perceived productivity, performance, and firm value gains are little or none. Not surprisingly, no methods are in use to evaluate C/B.

Rand McNally. This large private firm is the world leader in map publishing. GIS permeates its workforce, from executives down to operations personnel. GIS is used to create and update its map and electronic products, direct store delivery, i.e. locating and stocking retail outlines that carry its products, manage inventory, and provide specialized maps to marketing and planning departments. The costs are GIS software, development software tools, data, employment costs of GIS personnel, and time costs of spatial decision-makers, while the benefits are better decisions related to products and that the firm can create better maps.

Southern Company. This large parent utility company dominates electrical production and distribution in many parts of the southeastern U.S. Across its five operating companies, the largest spatial applications are asset management, followed by storm assessment/restoration, marketing, and network maintenance and inspections. Recently, it moved from distributed management of spatial technologies that differ among the operating companies, to an integrated and centralized enterprise-wide GIS. The GIS is internally-directed and is carefully planned to maximize enterprise returns on investment.

This case firm declined to give cost information but indicated spatial benefits were largely realized through the costly enterprise-wide systems described above, although there may be selective smaller opportunities. One area of clear benefit are map web services, since information can be distributed from a central location to a wide user base. Southern considers benefits very difficult to estimate due to the firm's complexity.

Sears Roebuck The giant retailer has extensive enterprise spatial technologies in six areas: routing and deploying service technicians, delivery, warehouse optimization, marketing, Sears Smart Toolbox (SST) provides automated vehicle navigation and capacity management of workforce in service territories. The scale is huge, for instance SST supports 10,000 technicians in all 50 states, and GIS/GPS systems support 5-6 million deliveries yearly.

Sears has invested significantly in long-term and large-scale GIS systems. However, the payoff has been high. The costs include a 12-person spatial team, annual data costs, high spatial development costs. For instance, its investment of a few million dollars for SST, its latest automobile navigation system, resulted in 10,000 GPS-referenced laptops being available on 10,000 delivery trucks that in turn improved delivery precision and improved efficiencies. The benefits are increased productivity multiplied across large workforces, faster delivery response and optimized pathways, and optimized re-arrangements of service territories. Traditional financial analysis with NPV is done, including computing payback periods. For its very large million-dollar-plus spatial projects, more advanced financial modelling is done. Part of the challenge is to take in to account the integration of spatial systems with legacy mainframe systems. This added cost of integrating systems is common for GIS (Tomlinson, 2003; Pick, 2005). The company has measured huge productivity and performance gains. The gains in the value of the firm are perceived to be there, but metrics do not yet break out the spatial contribution.

Kaiser Permanente. Kaiser is a national hospital chain centered in California that uses GIS especially in web map services, travel time analyses, travel accessibility studies, site selection, and some marketing and medical uses. GIS is important to meet regulatory requirements that dictate classification of areas as in-service versus out-of-service, to understand where clients are located and what disease profiles a region has, and to spatially analyze Kaiser health care resources including physicians, MRI equipment, and clinics. GIS is considered strategic for predicting member travel times, locational analysis, and facilities siting, but less so in the other areas.

The costs consist of people, hardware, and software, but also outsourcing since the GIS internal group at Kaiser had done occasional outsourcing of spatial tasks that are beyond their capabilities. An example was outsourcing to a consultant to implement maps and spatial analysis for the road networks around Kaiser facilities. The benefits have been in Kaiser's business decision-making, identification of catchment areas, maps included in submissions to government agencies, and maps for presentations and meeting discussions.

Case Findings for Medium-Sized Firms

Bay State Health. Bay State Health is a large New England health care system with three member hospitals in western Massachusetts, as well as associated laboratories, and medical service centers. Its eight-year-old GIS Program provides GIS for medical and health applications, environment, spatial statistics, spatial epidemiology, hospital facilities GIS, routing, marketing, and emergency and disaster planning and response. GIS is used internally based on client-server architecture. Its big applications were implemented recently, and GIS has not reached a strategic level in the organization.

The manager of GIS has performed relatively little analysis of costs and benefits. ROI analysis will be applied in the future. Currently at the most, a project managers decides on their intuition regarding costs and benefits. Hence the benefits cannot be determined. One of the reasons for the lack of C/B analysis at Baystate is that GIS group has been led by a champion, one of the system's top surgeons and a source of grant funding for GIS, so the GIS group falls more under grant project accounting scrutiny rather than administrative C/B. Another reason give is the small dollar amount of GIS projects so far.

Lamar Advertising Company. The third largest U.S. billboard firm, Lamar has 150,000 outdoor displays and 93,000 logo signs, mostly along highways. Lamar's biggest spatial application is to provide maps to its 900-person sales force to give in turn to customers who are considering alternative outdoor placements. Other applications are routing of its maintenance workforce and support for real estate acquisitions. Lamar utilizes an integrated, web-based platform that accesses mostly commercial data. However, its spatial-analysis functionality is limited. Since Lamar is unique among its competitors in having a spatially-enabled national billboard base, it draws strategic advantage especially in selling to customers.

Lamar's web-based spatial system incurs the costs of people, hardware, subscription to a commercial web service (ArcWeb Services). This has led to most benefits in sales, particularly in maps in proposals to customers and in closing contracts versus the competition. Sales people in the field have a very user-friendly simple mapping tool that produces simple, understandable maps for the advertising customers. C/B analysis is simple performance statistics of map usage and hit ratios

for sales proposals. Lamar perceives clear gains in productivity, performance, and firm value. However, performance is hard to measure, because GIS is connected to other systems such as contracts and billing and the integration.

Arizona Republic. The middle-sized newspaper focuses its spatial technologies on targeted advertising, particularly to identify markets by ZIP code and addresses for prospective advertisers, select carrier routes for target advertising, analyze trade areas for store advertising, and target non-subscribers through geodemographics for trial subscriptions to increase its circulation base. The Republic's GIS system is an enterprise, strategic tool, although the functional areas of application are limited.

The newspaper's GIS costs are people, software and maintenance, hardware infrastructure, data, and data conversion i.e. digitizing and geocoding. The main benefit reported is the competitive edge versus competing newspapers from the above applications. The GIS manager does not perceive productivity or performance gains, since he feels they are only at competitive norms and other technologies and equivalent gains could be achieved using other means without GIS. There is a perception of average performance from GIS, i.e. the newspaper has only had mediocre results with spatial technologies and they don't rise to a strong strategic level.

Western Exterminator. This middle-sized private firm employing 1,000 provides pest control management to residential and business customers in California, Nevada, and Arizona. The leading use of GIS is to plot the entire customer base for use by the sales force. GIS is also applied to re-align routing and to determine locations for new service centers. The firm utilizes predominantly commercial web services, adding some of its own map layers such as routing and service center locations. There are only internal users for the GIS - spatial staff and some service-center managers. The strategic advantages are to target homeowners, recognize underserved areas, and locate service centers.

Western Exterminator utilizes mainly a commercial map web service and realizes the benefits of improved marketing decision-making, siting, and vehicle routing. Although no formal C/B methods are used, the GIS manager perceives heuristically that there were gains in productivity and performance that were uneven across applications, and gains have occurred in firm value.

Case Findings for Small Firms

Engineering Systems. ES is a small consulting firm that provides GIS services to local governments as well as to utility and transport firms. Its in-house traditional client-server GIS serves its employees, although systems ES has installed in client firms serve varied external users. Some of its employees are assigned to client sites for extended periods, a form of outsourcing. The firm's in-house systems are not strategic, relative to its consulting competition, many of which have more advanced spatial analysis and/or web-based platforms that reach out to clients. Engineering Systems has costs of personnel, hardware, and software. It considers the major benefit the revenue gains for clients. The productivity, performance, and firm value gains are present for ES and derivative of the gains of its consulting client organizations. Since all ES products are GIS-related, ES responded that it uses its internal accounting system for metrics on spatial tangible costs and benefits.

Mapgistics This small health-care consulting firm provides geographic mapping applications to several hospitals with primary focus on one in southern California. The most important use is spatial analysis of bed management, with lesser uses in maps for emergency response situation, and a prototype application of spatial tracking of RFID-tags for certain types of patients. The costs have not been large, and concentrated in people, hardware, software, and financial. The biggest benefit is efficiency in bed occupancy and the patient discharge process. C/B methods for hospital clients are crude, comparing daily bed census and hospital revenues. C/B is not used in-house at Mapgistics. The rough methods have convinced the top manager of productivity, performance, and firm-value gains.

Motion-Based Technologies. This very small Bay-area firm was recently purchased by small to middle-sized technology company. MB serves performance athletes worldwide, by receiving and analyzing athletic performance training data uploaded from the athletes' GPS-enabled devices. The data are input into a data-base server and combined with topographic and routing data from commercial web services. Motion-Based has proprietary spatial-analysis software that computes customer profiles which allow these performance athletes to evaluate their route performance and compare it to their own performance and to the average performance of a cross section of athletes training on the same route. The spatial technologies which constitute the company's product are inherently competitive and strategic.

This firm's unique products lead to limited costs of personnel time for development of spatial applications, subscription to a commercial map web services product, and web servers. MB's benefits come from paid subscriptions, which currently are only 10 percent of customers. As a start-up, customers can use the web product's basic features for free, and there are not enough customers currently to attract web advertisers. Since MB has operated at a loss, the focus is on cost controls. This

means that C/B methods have limited applications, since tangible benefits are missing. Nevertheless, the top executive perceives productivity and performance gains, because the firm’s product itself is spatial. However, he also perceives that the quality and capacity of web services contributes more to firm value than spatial analysis.

A summary of key results from the cases are given in Table. 2. Shadings refer to size groups (large=blue, medium=white, small=grey).

Name or description	Size	Uses C/B Formal Method	Level of GIS Benefits	Strategic Level	Costs
Global Integrated Oil (description)	large	Yes	high	very high	people data
URS	large	Yes	high	medium	people software hardware
Large Credit Bank (description)	large	No	low	low	People, data software, hardware
Rand McNally	large	No	high	high	people, data, software tools, opportunity costs
Southern Company	large	Yes	high	high	NA
Sears Roebuck	large	Yes	high	high	people, data, hardware, software development
Kaiser Permanente	large	No	medium	medium	people, hardware, software, outsourcing
Bay State Health	medium	No	medium	low	undetermined
Lamar Advertising Company	medium	No	high	high	people, hardware, software, web services
Arizona Republic	medium	No	low	high	people, hardware, software , data, maintenance
Western Exterminator	medium	No	medium	medium	people, hardware, software
Engineering Systems	small	No	high	low	people, hardware, software
Mapgistics	small	No	high	high	training, hardware, software, financial costs
Motion-Based Technologies	small	No	high	very high	people, web services

Table 2. GIS Cost and Benefit Findings Related to Spatial Strategic Level and Firm Size

A number of conclusions can be drawn from the key findings.

- C/B methods are used predominantly by the large firms Small and medium-sized firms have not adopted formal C/B methods. Rather, for them C/B is done informally and often haphazardly. The explanation is that for the small- and medium-sized companies, in addition to staff shortages and lack of C/B standards, in many cases they do not have either sufficient experience or periods of profitability to allow standard methods to be systematically applied.
- The overall levels of perceived GIS benefits are high for large and small firms, but medium for medium-sized ones. The explanation for large firms is that, except for the large credit bank, they have trained and capable GIS staffs, that

have planned well, resulting in spatial benefits. For the medium firms, several have had less success with GIS, i.e. Arizona Republic and Western Exterminator. Baystate has rolled out major spatial applications only recently and had a champion who protected the applications from cost-benefit scrutiny. The small firms are accomplished in specialized applications, but are hard-pressed to achieve profits, which is not atypical generally of small companies. The reduced or absent profits means that there is less spare time for C/B analysis and that benefits are harder to identify.

- For large firms, both the level of perceived GIS benefits and use of C/B formal methods are associated with the firm's strategic level. It makes sense that more benefits are associated with greater strategic level for spatial. This is particularly true for a large firm with a long-term program of spatial applications. It gives sufficient success and adequate time for top management to perceive the benefits and identify spatial as a competitive weapon. The use of formal C/B methods are present because the large firms have standardized procedures and standardized expectations of controls. They are more mature in the sense of Nolan's Stage Theory model, which leads to presence of controls in its more advanced stages (Nolan, 1979). C/B methods may be present also because the GIS groups are intent on measuring and justifying their success with spatial technologies.
- For small and medium-sized firms, there is not an association between perceived benefits or uses of formal C/B methods and strategic level. This may be due to the growing pains of start-up and rapid growth. They are in the early stages of the Nolan model, in which controls have not been systematically put in place. Hence there is unevenness on whether such firm's have knowledge of the benefits or can formally measure them.
- The costs of GIS are fairly consistently reported as people, software, and hardware, with data often included for firms where large amounts of data are the responsibility of the firm, e.g. Global Oil, Large Credit Bank, Rand McNally, Sears, and Arizona Republic. For other firms, such as URS and Engineering Systems, their customers have a large amounts of data, but the firm itself is not directly responsible for collecting it and especially for maintaining it over long periods of time. Outsourcing is rarely cited as a cost -- only for Kaiser Permanente. The limited outsourcing may be due to the newness of spatial technologies in business, i.e. only in a big way over the past ten years (Tomlinson, 2003). Since it's new, there is not yet consistent and robust support coming from the outsourcing firms to dominate.

From the cases and summary analysis, the paper's Research Questions may be answered as follows.

1. *What are the important costs and benefits of GIS for the case study sample of fourteen firms.*

The most important costs are people, hardware, software, and data. The most important benefits are mapping quality, speed of mapping, better decision-making, increased productivity, enhanced reports and proposals, competitive edge, locating assets quickly, and improving efficiencies through spatial knowledge.

2. *Do large firms have more use of formalized methods of cost-benefit analysis than medium and small-sized ones?*

Large firms have much more use of formalized C/B methods. The most prevalent formal methods are NPV and ROI.

3. *Are the uses of cost-benefit analysis methods associated with high strategic value of GIS?*

For large firms, use of C/B methods is associated with high strategic value of GIS, but not for small or medium ones.

4. *Does the presence of full benefits (productivity gains, performance gains, and improved value) correspond to a high strategic level of GIS*

For large firms, presence of full benefits is associated with high strategic value of GIS, but not for small or medium ones.

CONCLUSION

Spatial technologies have expanded rapidly in the business world. Uses are evolving, supported by newer technology platforms, in particular the spatially-enabled, enterprise-wide web integration platform. As costs lowered, more profitable uses have been discovered. This research analyzed dimensions of spatial costs and benefits, and associates C/B to firm size and strategic level.

The research is exploratory. It has the weakness of small sample size, but the benefits of an intensive interview approach. Future research can test the framework and the research question with a large sample survey that would statistically evaluate

the preliminary findings reported here. That research might be further strengthened by interviewing or surveying varied levels of employees in each firm, to assess costs and benefits from a variety of organizational positions, perspectives, and stakeholders.

Managers in business should consider what opportunities are present to improve productivity, lower costs, enhance benefits, and strengthen strategic positioning through spatial technologies and GIS.

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