A Framework for Evaluating Public Sector Geographic Information Systems

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Introduction

One of the underlying assumptions of the NYS GIS Cooperative project is that GIS is a valuable public management tool, whose benefits could be enhanced through increased coordination. The project sought to identify the value of geographic information systems and spatial data in the public sector as well as mechanisms and opportunities for leveraging the benefits and minimizing costs. This value can be seen across a broad array of program areas. Consequently, substantial opportunity exists to share data, knowledge, and other resources across programs and sectors. Following is a discussion of mechanisms for evaluating public sector geographic information systems. Strategies for quantifying potential system benefits are presented. Opportunities for minimizing the costs and maximizing the benefits of GIS implementations are also discussed. The role of partnerships and information sharing is stressed in the context of maximizing the value of GIS in the public sector.

Evaluating Public Sector GIS

In general, evaluating the effectiveness or potential effectiveness of information systems is a difficult task. Evaluating information systems in the public sector presents additional challenges even in the case of more traditional technologies. "In the public sector, the scope of users, the type of decision the information system supports, and the other factors such as time pressures and accountability make information-system evaluation even more complex than in the private sector" (Newcomer, 1991, p. 378). The evaluation of public sector geographic information systems (GIS) is further complicated by the fact that the technology is relatively new, rapidly changing, and being utilized to support an increasingly diverse array of application areas.

The development of a mechanism to evaluate the system is a difficult but necessary component of GIS implementation. Evaluations can be conducted for the following three purposes:

- to assess the resources needed to implement a GIS project
- to make a case for investment in a single project or to evaluate the relative merits of several alternative projects
- to provide a benchmark for assessing the success of a project

While the need to evaluate GIS is clear, the process for doing so is much less clear. "From a review of the literature, it would appear that the task of cost-justifying investment in GIS in local government has proved difficult and that some GIS implementations are more an act of faith than the result of critical evaluation" (Worrall, 1994, p. 545). Brudney and Brown (1992) echo this sentiment. "Despite the rising number of government agencies investing in GIS, little is known about the potential costs and benefits that this technology can bring to the public sector" (p. 84).

An evaluation of a GIS project requires a clear statement of the purpose or goals of the implementation as well as a thorough analysis of the components necessary to support those goals. The evaluation should then be conducted in terms of the specified goals of the implementation. In particular, the "real" things that will be affected must be identified and, wherever possible, a monetary value should be applied to the expected outcomes and the expected costs.

Cost-Benefit Analysis

A commonly used methodology for evaluating information systems prior to implementation is cost-benefit analysis. Cost-benefit analysis is a tool used to support decision making in the public sector. It is similar to financial analyses conducted in the private sector to assess new projects. Cost-benefit is distinguished from financial analysis in its inclusiveness of all benefits and costs related to a decision. Unlike in the private sector where only those dollar values which accrue to the individual firm are included in the analysis, public sector decision makers should consider all of the costs and benefits (Smith and Tomlinson, 1992).

Sugden and Williams (1978) indicate that the objective of cost-benefit analysis is the maximization of social welfare. They discuss cost-benefit analysis in terms of the 'potential pareto improvement criteria.' This criterion states that a project should be undertaken only if the gainers from a project could fully compensate the losers from the project such that gainers themselves do not become net losers. This criterion, however, does not require that the gainers actually provide that compensation. In other words, the effects of a project should be evaluated based on the 'willingness to pay' of the individuals affected by the project, as opposed to an actual transfer of resources. The favorable effects comprise the sum of the money that the beneficiaries would be willing to pay while the unfavorable effect is measured by the minimum sum of money that the losers or sufferers would be willing to accept as compensation for tolerating the project. The authors also indicate that some decision makers do not accept the potential pareto improvement criteria as sufficient. Using willingness to pay as the basis for valuations creates a 'market' concept of value. Furthermore, using the willingness-to-pay principle assumes equal weight for each dollar's worth of consumption, regardless of who the consumer is. For a variety of reasons, decision makers may prefer to apply different weights to different groups of people.

Smith and Tomlinson (1992) summarize the steps involved in cost-benefit analysis as follows: 1) Specify the objective or desired outcome of the activity in question and determine all relevant impacts; 2) use identified impacts to define all costs and express these in dollars of the base year; 3) identify positive impacts (benefits) occurring over time and assign dollar values for the base year; 4) benefits and costs spread over a period many years into the future must be discounted to the base year using a discount rate to capture the time value of money; 5) the appropriate decision

criterion is that socially desirable projects should generate positive net present values (NPV) or a benefit-cost ratio greater than one. The NPV is derived by subtracting the present value of costs from the present value of benefits (NPV=PVB-PVC) while the benefit-cost ratio is computed as B/C=PVB/PVC.

Cost-Benefit Analysis for Geographic Information Systems

While the steps involved in conducting cost-benefit analysis are relatively straightforward, the process of assigning monetary values to all of the associated costs and benefits often poses some difficulty. These difficulties have led to a discussion in the literature of the appropriateness or feasibility of using cost-benefit analysis in the evaluation of GIS implementation.

Dickinson and Calkins (1990) suggest that the detailed information needed to support traditional cost-benefit analysis of geographic information systems is not always readily available for three reasons. First, it is often difficult to identify and describe the level of demand for those products the GIS is designed to support. It is often difficult to assess the demand for products resulting from system implementation. This process of identifying value is particularly difficult when the resulting products are new or substantially different from those of the manual process and further, as system familiarity increases within an organization, the uses of a system and subsequently the level and diversity of products may increase. Second, it may be difficult to estimate the economic or dollar value for all of the system products. Last, some of the objectives or goals of a GIS implementation may not be readily expressed in terms of discrete products.

In order to overcome these obstacles, which reflect difficulties in estimating only the "benefit" side of the equation, Dickinson and Calkins suggest differentiating between those benefits which are quantifiable in monetary terms and those which are non-quantifiable. They further suggest that a complete economic evaluation have three parts. The first would be traditional cost-benefit analysis. The second would be a cost-performance calculation, the goal of which would be to capture those benefits associated with either a decrease in the cost of a given level production or an increase in performance associated with a given level of cost. These benefits, they contend, are different from those *added* benefits associated with system implementation and should therefore be reported separately. The third part of the evaluation would be an order-of-magnitude estimate of the non-quantifiable benefits. They indicate that the benefits which are non-quantifiable are associated with those implementation objectives stated as improved decision-making processes, the reduction of risk, and the reduction of uncertainty.

Wilcox (1990) contends that the suggested alternatives to estimating benefits are unnecessary. She argues that the differentiation of benefits into added or "cost-performance" is unnecessary and that all benefits associated with system

implementation should be included in the cost-benefit ratio. She also indicates that "In reality there are few occasions where information is genuinely unobtainable, either directly or by proxy" (p. 206). The concept of intangible or "non-quantifiable" benefits as suggested by Dickinson is unnecessary under this assumption. Wilcox also addresses the difficulties of assessing system objectives such as "improved decision-making." She indicates that this problem is a function of the system requirements analysis and not a limitation of cost-benefit analysis. These objectives must be broken down into component factors: how much will a system improve decision-making and through what features and mechanisms? What queries will be made to the system? What features must be included in the system to enhance decision-making? These issues must necessarily be addressed in the system design and should therefore be available for the evaluation. "If the goals can be stated no more specifically than 'to improve a decision-making process,' the implementation of the GIS cannot be sufficiently justified: the user could not effectively utilize the system" (p. 207).

Wilcox concludes that further exploration of the incorporation of techniques such as structured systems analysis into the cost-benefit analysis may provide a clear framework for ensuring accurate and complete system evaluations. She also stresses that the notion of using cost-benefit analysis to evaluate GIS implementations should not be abandoned.

Smith and Tomlinson (1992) similarly conclude that the suggested supplements to cost-benefit analysis offered by Dickinson and Calkins are unnecessary. "Contrary to this suggestion, we argue that straightforward cost-benefit analysis remains the best framework for analyzing the contributions of a GIS and that the supplements that they recommend are generally not necessary" (p. 248).

For the most part, these arguments indicate that cost-benefit analysis is an appropriate tool for evaluating GIS implementations. There is consensus on the point that some of the parameters needed to support the analysis, particularly estimates for potential system benefits, are difficult to obtain. Further, economic methodologies such as estimation of willingness to pay, risk analysis, and derived demand can offer assistance in quantifying system benefits. For benefits related to improved decision making, specific information as to which decisions will be improved and how, should be available from the system needs analysis. In other words, the specific potential benefits of the system should be clearly identified as objectives of the implementation, and the valuation of system benefits should be closely linked with these objectives. "A cost/benefit analysis forces one to define one's objectives. It also affords an opportunity of checking whether or not one is pursuing the predefined objective" (Joint Nordic Project, 1987, p. 42).

There is a cost associated with gathering information to support a cost-benefit analysis. If the more easily quantifiable benefits yield a positive net present value for the implementation, consideration should be given prior to expending more resources to improve the ratio.

Lastly, the parameters entered into a cost-benefit analysis are in many cases, estimates or best guesses. A rigorous analysis should include sensitivity analysis where ranges of values for parameters are examined in light of their impact on the overall ratio.

In analyzing the potential return on investment for a GIS to support the South Florida Water Management program, it was determined that the system could be justified considering only productivity gains. According to GIS project manager Robert T. Brown, III, "Productivity was the only thing that we felt we could defend, the only thing we had numbers for but we did acknowledge the intangibles, and we probably would have focused on them more if we needed them to justify the system" (Pastore, 1994, p. 37). Brown further indicated that the return on investment (ROI) prediction process was not without frustration and that it was difficult to estimate the number of projects that the GIS would support. He also indicated that their approach emphasized erring on the conservative side.

The Florida Water Management Office experience summarizes both the difficulty and potential mechanisms for dealing with the difficulties of evaluating a GIS system. First, the demand for potential GIS products is often difficult to assess, particularly in those cases where the products are not available under the current system. In these cases, the analysis should err on the conservative side and set realistic expectations. Further, some of the benefits are more difficult to quantify than others, and it is therefore recommended that the evaluation be conducted with the more readily obtainable data first. Further resources should be expended on the collection of additional information to support the analysis only if necessary to justify the implementation or to make valid comparisons of alternative implementations.

Costs

Dickinson and Calkins (1990) suggest the following cost categories and further stress that many of these costs are over and above those associated with initial system acquisition and should therefore be reported for each fiscal year of the system's expected life.

- Feasibility Study (needs assessment, preparation of RFP, benchmarking)
- Hardware (CPU, workstations, telecommunications)
- Software
- Hardware maintenance contracts
- Software maintenance contracts
- Database entry/transfer
- Database maintenance (edits, updates, backups)
- Training
- In-house programming for software enhancements (macros, interfaces)
- In-house support for system users

- Actual running of applications on the system (i.e. salary of applications specialist, system staff, or system operator)
- Supplies (paper, plotter pens, blank tapes)
- Overhead (machine space, climate control)

In addition to these costs, we suggest the following:
- Information dissemination
- Archiving and records management
- Business process reengineering

As GIS use increases it would be expected that the demand for digital spatial data will also increase. A public agency should expect some costs to accrue from the dissemination of spatial data sets. These costs may be implicitly included in the "database entry/transfer" category above but we suggest an explicit representation of these costs as they are closely linked to the benefit side of the equation. These costs may be somewhat difficult to estimate as the actual level of demand may be unknown. However, estimating the level of demand for data and data products will yield more comprehensive cost estimates and further will be useful in the calculation of benefits as discussed more fully below.

Also important in calculating total system cost are those costs associated with an agency's record management and archival requirements. These considerations are often omitted in both system design and cost considerations. Processes and media for records management and archiving should be identified their costs identified.

As in the case of other technologies, GIS offers substantial opportunity for the reengineering of business processes. Maximum benefit will be derived from a system if opportunities for process reengineering are identified and implemented. Resources should be allocated to support BPR efforts in conjunction with the system needs analysis and implementation.

As the costs of data conversion often comprise a substantially large proportion of total system cost, particular care should be given to the estimation of these costs. Estimates should be based on actual samples of agency data for all required data types. Costs of all steps involved in data acquisition need to be considered and incorporated into the analysis, including identifying the sources and quality of existing data, any necessary sorting, reindexing, data cleaning, or edgematching.

Benefits

While the costs of GIS implementation can be closely approximated through a careful assessment of hardware, software, training, and data conversion costs, the estimation of the potential system benefits is often more difficult. "While the costs of GIS are

relatively easy to assess and highly 'front-loaded,' benefits are often difficult to measure and usually arise well into the life of a project" (Worrall, 1994, p. 545).

Brudney and Brown (1992) identify three categories of potential GIS benefits in the public sector: improved performance and efficiency, enhanced decision making, and improved service to the public. Worrall (1994) indicates that effectiveness is a measure of the impact of policies and programs while efficiency is geared toward a maximization of the ratio of outputs to inputs.

The notion of improved performance and efficiency suggests that with the use of GIS technology, organizational performance can be enhanced at substantially lower cost than without the use of technology. For example, the use of GIS can lead to increased performance in many government processes which require the use of disparate information retrieval processes such as the issuance of land use permits. Additionally, GIS technology allows for such activities as comprehensive zoning and the evaluation of capital improvements which are infeasible or extremely costly without the technology. Further, improvements in performance related to the implementation of GIS technology can result in increased efficiency.

The comprehensive nature of GIS can lead to improvement in organizational decision making. An integrated system will serve to minimize data redundancy and allow for more comprehensive and systematic approaches to decision making. The realization of these benefits is highly dependent on the ability of an organization to unite its disparate data on a common platform. "Because GIS centralizes disparate information services in one system, an organization can reduce personnel overhead and associated expenses" (Brudney and Brown, 1992, p. 85).

An additional benefit of GIS use is related to improved service to the public. Often a system is proposed in reaction to a service delivery problem. The ability to integrate disparate data types into one system offers potential for substantial improvements in response time to customer inquiries. GIS, supported by its information integration and visual display capabilities, also provides an enhanced vehicle for communication with customers. As the saying goes, "a picture is worth a thousand words." Additionally, the use of GIS can offer expanded or additional services to customers. GIS can support the integration of data from various departments and even across agencies, supporting "one-stop-shopping" for information. Moreover, the technology allows data to be condensed and analyzed in a number of different formats.

Maximizing Benefits

Five recommendations for maximizing the benefits of a GIS are discussed below. They include:

- identification of all potential stakeholders
- development of internal and external partnerships

- integration of GIS with organizational information resource management strategy
- identification of areas for business process reengineering
- identification of potential for revenue generation

Identify all potential stakeholders

In calculating prospective system benefits, a comprehensive analysis will include an identification of all of the stakeholders, the winners and the losers. In order to identify all of the potential benefit, both internal and external stakeholders should be identified and the benefit to each quantified. Benefit can be derived from both the system outputs and the data created to support the system. As indicated above, even if the gainers (for example, other agencies benefiting from the use of data) do not compensate the losers (the agencies paying for the creation of the data) this benefit should be counted. This is also the case for improved or enhanced service to customers. If the enhanced service made possible by the implementation of a GIS is of value to customers, in other words, if they would be willing to pay some amount for it, this "benefit" to the customer should be included in the analysis even if the transfer of funds does not occur. "The total willingness to pay of all users for such GIS produced data should enter into the calculation of benefits" (Smith and Tomlinson, 1992, p. 248).

Develop internal and external partnerships

Partnerships both within and between organizations will also increase the benefits of GIS. Effective partnerships allow for the sharing of expertise which allow the needs of the various partners to be met at minimized cost. Potential partners can be sought within an organization, from adjacent cities and counties, regional authorities, school or park districts, utilities, and private developers. While partnerships offer such advantages as sharing data and costs for equipment and system development, they also have the potential to increase the complexity of negotiations over costs, accuracy requirements, responsibility, and controls. Therefore, partnerships should be developed carefully and expectations should be clearly communicated.

Integrate the GIS with organizational information resource management strategy

Another suggested strategy for increasing the cost-effectiveness of a system is the integration of GIS into the organizational information resource management strategy. While it may be difficult to assess and prioritize the needs of diverse users within an organization, the literature emphasizes that substantial benefit can be realized from doing so. The value of inter-organizational cooperation includes a potential reduction in system costs as well as the potential for improved organizational decision making as

discussed above. Studies have shown that for those applications which replace manual cartographic production, benefit-cost ratios of about 1:1 were realized. For those where coordination has been achieved between different activities sharing the same information, ratios of at least 4:1 should be attainable (Joint Nordic Project, 1987). When departments jointly plan and organize a GIS, they may stimulate better communication and cooperation with consequent benefits in government decision making (Dangermond, 1989).

Identify areas for business process reengineering

While a technology implementation can result in increased productivity and improved quality of services, maximum benefit is often realized by using the technology innovation as a catalyst for process reengineering. "If IT's potential for business change is to be achieved, it must be viewed as an enabler of process innovation" (Davenport, 1993, p. 47). "If a GIS is to be used to transform an organization, rather than to automate procedures, the GIS cost-benefit case is likely to be more favourable" (Worrall, 1994, p. 547). A careful analysis of the processes that the system is intended to support will allow for more effective system design as well as opportunities for reengineering. Workflow analysis provides opportunities for quantifying savings that might accrue through an injection of change to a business process (Putnam, 1995). A proposed system implementation provides a lens through which an organization's processes can be viewed and opportunities for streamlining or eliminating entire processes can be identified. Additionally, through the use of distributed systems, organizations may be able to change the way they communicate and share information.

Identify potential for revenue generation

GIS technology enables information to be aggregated in new and useful ways. Data generated by a local government, for example, has value to other government agencies as well as to value-added resellers and other private sector entities. Opportunities therefore exist for that local government to generate revenue. These potential benefits should not be omitted from the analysis.

Minimizing Costs

We recommend four ways to minimize the costs of GIS:

- Careful analysis of data needs
- Use of existing data sets
- Sharing the costs of data creation and conversion
- Share infrequently used equipment

Careful analysis of data needs

As indicated above, data conversion and maintenance costs comprise the largest proportion of total GIS costs. The costs and benefits of creating or converting data should be carefully considered. While some datasets are absolutely necessary to support the system objectives, the costs of converting or creating others may far outweigh the benefits that they will yield. In addition to choosing which data sets need to be converted, different mechanisms for conversion and records management should also be carefully compared. Selection among these various options will have a substantial effect on overall system development and maintenance costs. Worrall (1994) indicates that many local authorities have spent years developing databases without ever producing any benefit as data sets are either incomplete or the system itself is tied up in data capture activities. In order to avoid such a situation he suggests that one "phase and plan data conversions so that some benefits are achievable early on in the implementation. It is advisable to identify which benefits can be won without the full implementation of the data model, to have a clear understanding of users' priorities and to manage their expectation of what is achievable (though with vendor hype, managing expectations may be difficult)" (p. 559).

Use existing data sets

In many cases, data needed to support an application already exists either from another public sector entity or from a private vendor. While it is often difficult to identify the sources and quality of existing data sets, information should be gathered from the data owners as well as from secondary users of data in order to identify the most appropriate and cost-effective data source. Quality and accuracy considerations must be considered in light of increased cost considerations.

Share the costs of data creation and conversion

In those cases where needed data does not already exist, opportunities should be sought for partnering in data creation activities. Other entities either within or external to an organization may have use for a specific data layer or set of layers. In other cases, economies of scale can be realized if data creation efforts for adjoining geographic entities are conducted together. These different types of partnerships can serve to substantially diminish overall data creation costs.

Share infrequently used equipment

Total system costs can also be reduced if peripherals or other hardware can be shared either within an agency or across agencies. If equipment is needed only for up-front data conversion and/or infrequent interval updates, opportunities for sharing should be explored.

Conclusions

An important component of any GIS implementation is an evaluation of the potential system costs and benefits. A system evaluation should be closely tied to specific system objectives and a comprehensive and explicit needs analysis. The real things that will be affected by system implementation need to be expressed in terms of increased efficiency, effectiveness, and improved or extended service to customers. Expected improvements in decision making must be explicitly described in terms of the effects and value of these improvements. Cost-benefit analysis is an appropriate framework for such an evaluation. While some system benefits are difficult to quantify, mechanisms such as risk analysis, derived demand, and willingness-to-pay can be used to express these benefits in monetary terms. A number of strategies can be used to improve a cost-benefit ratio. In particular, a system implementation should be viewed as an opportunity or lens through which business process reengineering can be conducted. System value can also be maximized by integrating a GIS into an agency's overall information strategy. As the costs of data creation or conversion often comprise the largest component of total GIS costs, strategies for reducing these costs can substantially improve the ratio. Partnerships also serve to both maximize the benefits and minimize the costs of system implementation.

Bibliography

Brudney, J.L. & Brown, M.M. (1992, Spring). Do geographic information system meet public manager's expectations? *State and Local Government Review,* 84-90.

Dangermond, J. (1989, Summer). The organizational impact of GIS technology. *ARC News*, 25-26.

Davenport, T.H. (1993). *Process innovation reengineering work through information technology.* Boston: Harvard Business School Press.

Dickinson, H.J. & Calkins, H.W. (1990). The economic evaluation of implementing a GIS. *International Journal of Geographic Information Systems*, **2**, 307-327.

Dickinson, H.J. & Calkins, H.W. (1990). Comment on 'Concerning the economic evaluation of implementing a GIS'. *International Journal of Geographic Information Systems*, **4**, 211-212.

Joint Nordic Project 1987. Community benefit of digital spatial information final report conclusions and recommendations. Nordisk Kvantif.

Mounsey, H. (1993). Accurately estimating the costs of Using GIS. *Proceedings of the IIR Conference on GIS: Weighing the Costs and Maximising the Benefits* (London: IIR Ltd.), **4**, (1-4) 13.

Newcomer, K.E. & Caudle, S.L. (1991). Evaluating public sector information systems: more than meets the eye. *Public Administration Review*. **5** (1,5), 377-384.

Pastore, Richard. (1994, January 15). A valuable eco-system. *CIO*, 36-38.

Putnam, D.S. & R.S. Moore. (1995). Reengineering the property appraiser's office: more than a GIS. *URISA Proceedings*, 509-519.

Smith, D.A. & Tomlinson, R.F. (1992). Assessing the costs and benefits of geographical information systems: methodological and implementation issues. *International Journal of Geographic Information Systems*, **6**, (3), 247-256.

Sugden, R. & Williams, A. (1978). *The principles of practical cost-benefit analysis.* Oxford: Oxford University Press.

Worrall, L. (1994). Justifying investment in GIS. *International Journal of Geographic Information Systems*, **8**, 545-565.

Wilcox, D.L. (1990). Concerning 'The economic evaluation of implementing a GIS. *International Journal of Geographic Information Systems*, **4**, 203-210.

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