31

GIS SPECIFICATION, EVALUATION, AND IMPLEMENTATION

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A general model for GIS acquisition is presented, involving four stages: analysis of requirements, specification of requirements, evaluation of alternatives, and implementation of the selected system. The steps involved in each stage are described. A cost-benefit analysis is used to determine the merits of the proposed acquisition, and a cost-effectiveness analysis is used to evaluate the functionality and performance of alternative systems. The thoroughness of the user requirements analysis and the management of the organizational impacts of GIS acquisition are considered to be critical success factors.

INTRODUCTION

Private or public sector agencies which utilize spatial information may consider, or be advised, that GIS technology would improve the efficiency or effectiveness of their operations. How should such agencies determine whether this is true? Should they develop the system in-house or acquire an existing system? How should they determine which existing system to acquire? What are the critical success factors when GIS technology is implemented for the first time? These are the fundamental questions addressed in this chapter.

Many early GIS were developed by research and development staff within user agencies. Some initial experimental systems developed into operational systems. However, the complexity of current GIS technology and applications is such that this approach is now rarely pursued. The time, costs, and risks involved in development and maintenance of major computer systems, combined with the availability of commercial GIS software, means that most agencies now choose to purchase an existing system, perhaps with some customization, rather than developing their own. This latter approach is assumed in this chapter.

Perusal of this book and other GIS literature (e.g. issues of the periodicals *GIS World* and *Mapping Awareness*) will reveal that there are many vendors of GIS technology and a number of systems are in the public domain. These commercial and public systems exhibit a wide range of functional capabilities, system configurations, data structures, performance characteristics and costs. There is minimal public domain literature comparing the various systems, and their features are changing so rapidly that any such literature is soon out of date. A methodology is therefore required for an agency to determine whether the benefits of acquiring GIS technology are greater than the costs, and if they are, to decide which system to acquire.

The methodology presented here is in the form of a general model for the analysis and specification of GIS requirements, the evaluation of alternative systems, and the implementation of the selected GIS. The 14 steps in the model are described in the next section. In a final section, some management issues and critical success factors associated with the introduction of GIS technology are outlined.

A GENERAL MODEL FOR GIS ACQUISITION

The model presented here is based on current systems development and project management practices, adapted to the GIS environment. It incorporates aspects of the GIS design and evaluation work of Marble *et al.* (1972), Calkins (1983), Dangermond, Freedman and Chambers (1986), Clarke (1988), Guptill (1988) and Bromley and Coulson (1989). The GIS acquisition model comprises four stages, each with a number of steps (Table 31.1).

Table 31.1 The GIS acquisition model.

Stage	Step
Stage 1: Analysis of requirements	
	1. Definition of objectives
	2. User requirements analysis
	3. Preliminary design
	4. Cost-benefit analysis
	5. Pilot study
Stage 2: Specification of requirements	
	6. Final design
	7. Request for proposals
Stage 3: Evaluation of alternatives	
	8. Shortlisting
	9. Benchmark testing
	10. Cost-effectiveness evaluation
Stage 4: Implementation of system	
	11. Implementation plan
	12. Contract
	13. Acceptance testing
	14. Implementation

The importance of a particular step will vary from project to project and the costs involved must be kept in proportion to the size of the GIS. For small projects, steps such as the pilot study may be omitted and the issues involved in some other steps addressed very quickly.

Stage 1: Analysis of requirements

The first stage is an iterative process for identifying and refining user requirements, and for determining the business case for acquiring a GIS. After each step is completed, the resulting report should be discussed with users and management, and the conclusions from the previous steps should be re-examined and, if necessary, refined.

1. Definition of objectives

The objectives of this step are to define the scope and objectives of the GIS acquisition project, and to obtain management and user support for them. The activities are:

- Review overall agency objectives.
- Develop GIS project objectives.
- Negotiate with management and users.

The acquisition of a GIS must be compatible with the agency mission statement and business plan. Those documents should provide a framework within which specific project objectives can be developed. Objectives should be stated from management's perspective, focus on results and be measurable. Key aspects include cost, time, quality, accuracy and staff impact. Vague statements regarding new technology or improved decision making are not adequate. Users must also be satisfied that the project will result in benefits for them.

The outcome from Step 1 is a document which has management and user endorsement and which commits the agency to proceeding through to a GIS cost-benefit analysis (Step 4). The agreed objectives may, of course, be refined after further analysis.

2. User requirements analysis

The objectives of this step are to determine the user requirements upon which the GIS will be designed and evaluated. The output from a GIS is an information product, obtained by processing geographical data. Three levels of user requirements can therefore be identified: information, processing and data. The analysis activities are:

- Assess existing information, processes and data.
- Identify potential GIS users.
- Define required information products.
- Analyse data requirements.
- Estimate workloads and required performance.

The initial assessment should result in an understanding of what information is being used, who is using it, and how the source data are being collected, processed, stored, and maintained. This is the base against which the alternative of acquiring a GIS will be tested. The required information can be obtained through interviews, documentation reviews and workshops. The report should clearly identify the work flows which relate to spatial data, as well as the characteristics of those data including source, accuracy, format, and volume. The costs of operating those parts of the current system which may be replaced by the proposed GIS must also be identified for use in the cost-benefit analysis.

Potential GIS users include the users of information products (decision makers), people who process data to obtain information (applications specialists) and people who collect and maintain data. For some agencies these functions may be performed by an individual, while for others they will be performed separately by many people. The end-product users may be external clients for whom the agency provides a service. The process and data users will be hands-on users of the proposed GIS and should be relatively easy to identify based on the current systems and processes. However, potential end-product users may include decision makers who do not currently have access to geographical information products due to time, cost or availability constraints. These may be the most difficult and important potential users to identify (Guptill 1988).

The definition of required information products is the key to the user requirements analysis. Products may be in the form of hardcopy and softcopy graphics and reports, and digital data in a range of formats. Applications and data capture staff may require a range of intermediate products for verification purposes. The current geographical information products provide the starting point for determining user needs, but there may well be potential for new and enhanced products. The GIS product definition process should result in a clear statement of the media, format, and content of the required information products.

Data requirements are determined directly from the product definition. The analysis should identify the classifications, accuracy, and update frequency required for each data type.

Workshops and demonstrations may be necessary to explain the options and issues in defining product and data requirements. Structured methods for requirements analysis such as strategic data planning, decision analysis and modelling may also be appropriate (McRae and Cleaves 1986).

The final activity in Step 2 is to estimate the workloads and required performance characteristics of the GIS. These will have a large impact on the proposed hardware configuration and hence on costs. Important aspects include the number of simultaneous users, data volumes, response times, and required production rates. A formal model for GIS workload estimation has been developed by Goodchild and Rizzo (1987). The model uses a library of sub-tasks from which GIS products can be produced, measures of use which represent some demand on the system, and a set of predictors for those measures. The ability of proposed systems to achieve the required performance is evaluated during benchmark testing (Step 9).

The analysis of user requirements may lead to some refinement in the definition of objectives.

3. Preliminary design

The information gathered during Step 2 enables a preliminary design for the GIS to be developed. The design will be used for the cost-benefit analysis of the proposed GIS, and will enable specification of the pilot study. The preliminary design step activities are:

- Develop preliminary database specifications.
- Develop preliminary functional specifications.
- Develop preliminary system models.
- Survey the market for potential systems.

The classifications, accuracy, and update frequency for each data type were identified during the analysis of data requirements. The preliminary database specifications must also identify the sources, volumes, and structures for both spatial and attribute data. Preliminary consideration must be given to the choice of vector or raster (or both) spatial data model and to whether a fully relational or other model is required for attribute data.

Functional specifications are determined directly from the product definition in Step 2 and the database specifications. They define the functions and processes which are required to enable the database to be developed and the information products to be produced. A detailed checklist of generic GIS functions is provided by Guptill (1988) for user interfaces, database management, database creation, data manipulation and analysis, and data display and product generation (see also Maguire and Dangermond 1991 in this volume). The specifications must also identify the requirements for batch, interactive (or both) processing modes for particular functions.

Conceptual models should be developed and documented to describe the logical and physical design of the proposed system. Aspects include hardware, software, communications, processes, people, and organizational arrangements. Alternative models for the hardware and communications architecture may be included. For some agencies, the choice between a distributed and centralized GIS may be a critical design issue. Dangermond (1988) reviews the trends, advantages, and disadvantages of the various GIS architectures.

A market survey should then be conducted to determine the capabilities of systems in relation to the preliminary design. Initially, this may be done through visits to vendors and user sites. The objective is to determine whether the preliminary specifications can be met with current technology. If not, the options are to lower the functionality and performance specifications, or to accept that a major system development component may be included in the acquisition. This informal market survey could be conducted in conjunction with Steps 1 and 2 and the previous activities in Step 3.

A formal market survey involves issuing a call for expressions of interest from GIS vendors, based on the preliminary system specification. The objectives are to identify potential suppliers and the nature of their products, and to advise vendors formally of the agency's GIS plans. This enables the agency to refine the preliminary specifications and system models, and the vendors to prepare for the request for proposals (Step 7).

4. Cost-benefit analysis

The objective of the cost-benefit analysis is to establish the business case for the GIS acquisition proposal. The costs, benefits, impacts, and risks of acquiring a GIS are measured against the alternative of continuing with the current data, processes, and information products. If the preliminary design models include fundamentally different approaches, such as distributed versus centralized systems for an agency with regional offices, it may be necessary to analyse the costs and benefits of the alternatives. The cost-benefit analysis activities are:

- Estimate all costs.
- Identify all benefits.
- Estimate economic value of quantifiable benefits.
- Assess impacts on organization and staff.
- Assess risks.
- Analyse results.

Costs for GIS implementation and operation include those for acquisition and maintenance of hardware and software, data capture and maintenance, training, additional and more highly qualified staff (required for system management, in-house programming, user support and the running of applications), consumables, site preparation and all associated overheads. The cost of the acquisition process may also be included. Recurrent costs should be determined over a nominal system life of at least five years, discounted to present value. Discounting reflects the opportunity cost of capital and enables comparison of costs and benefits which occur at different times during the system life.

Indicative hardware, software, maintenance and training costs should be obtained from two or three appropriate vendors identified during Step 3. If possible, these costs should be validated by discussions with existing user agencies. Data capture costs may range from 10 to 1000 times the hardware and software costs (Guptill 1988). Models of the manual digitizing process developed by Marble, Lauzon and McGranaghan (1984) and Lai (1988) provide a basis for costing this component.

Three categories of GIS benefits may be defined: efficiency, effectiveness and intangible (Prisley and Mead 1987; Maffini and Saxton 1987). Efficiency benefits relate to time and cost savings through faster data processing and a reduction in duplicated effort, while effectiveness benefits relate to improvements in the decision-making process through more timely or new information. Intangible benefits may include an improved public image for the agency, a reduction in confusion caused by contradictory data, improved cooperation between users through data sharing, increased staff professionalism and morale, better ability to cope with unexpected events, new knowledge through improved data analysis and unanticipated applications.

While an economic value can readily be assigned to efficiency benefits, the effectiveness and intangible benefits are harder to quantify. Dickinson and Calkins (1988) and Dickinson (1989) describe methods for estimating the economic value of non-quantifiable GIS benefits. However, Dickinson and Calkins (1988) also recommend that such values be reported separately as they have a larger element of uncertainty. Chorley (1988) argues that rather than quantifying benefits which are inherently intangible, it is more appropriate to provide a clear description and analysis of such benefits to enable judgement by senior decision makers.

The impacts of the proposed GIS on the organization and staff of the agency may be major and so could have a significant bearing on the cost-benefit analysis. The impacts on data collection, data processing, and decision-making staff can be assessed from the user requirements analysis. The impacts on the organization may include changes to the organizational and management structure associated with new technology, new roles and procedures, and new requirements for consultation and cooperation. These institutional issues may have a larger influence on the success of the GIS than technical issues (Foley 1988; Seldon 1987). Early consultation with staff and their representatives regarding these impacts will help to avoid disputes during implementation. There may also be political and legal implications for the agency in terms of responsibility, authority and guarantees associated with the collection and maintenance of data and the dissemination of information products.

The cost-benefit analysis should include an assessment of the risk that the project will not achieve a successful outcome in terms of time, cost, specifications, and benefits. Economic risk may be assessed through a sensitivity analysis by determining the most pessimistic and optimistic values for the quantified costs and benefits. Other risk factors include the complexity of the data and system being considered, the experience and composition of the GIS project team, and the anticipated impact of the system on the organization and staff. Describing risks at this early stage enables senior management either to take action to reduce the risks, or to monitor them closely during the project.

The costs, benefits, impact, and risks may be analysed and presented in a number of ways. Dickinson and Calkins (1988) describe a benefit/cost model based on GIS product values. Griffin and Hickman (1988) describe results of analyses of the present value, savings and investment ratio, discounted payback, breakeven and benefit–cost of an implemented GIS. The minimum requirement is to present the basic economics of the proposal, together with a statement of factors not included in the economic analysis. The basic economic equation is:

operating cost of the system to be replaced
− operating and capital cost of proposed GIS
+ quantified benefits of proposed GIS
= net economic benefit of the proposed GIS
± sensitivity

This net economic benefit must then be assessed against concise statements of intangible benefits and risks, and the impacts on the organization and staff.

Consideration of the cost-benefit analysis is a major milestone in the GIS acquisition project. It may indicate that the proposal should be deferred, that further work must be done on the objectives, requirements and preliminary design, or that the acquisition should proceed to the pilot study step.

5. Pilot study

The primary objective of the pilot study is to test the preliminary GIS design before finalizing the system specifications and committing major resources. Secondary objectives are to develop the understanding and confidence of users in the technology, by demonstrating applications with their data, and to gain some operational experience to assist design of the benchmark test (Step 9). The pilot study activities are:

- Design the pilot study.
- Select a pilot system.
- Acquire pilot data.
- Produce pilot products.
- Analyse results.

The pilot study design document must state the study objectives, address the selection of the pilot system, data and products, and identify the required resources and proposed timetable. It is important for the users to agree the objectives and scope of the pilot study.

A number of potential systems will have been identified during the preliminary design step. The selection of one for the pilot study is based on the apparent match of capabilities to requirements, and the cost of establishing the pilot system. Hardware and software may be leased for the duration of the pilot, or vendors may be prepared to loan systems and provide support. However, it must be emphasized to all parties that the choice of a system for the pilot does not pre-empt the decision on which system will be finally acquired. Users must avoid the pitfall of becoming committed to the system chosen for the pilot through their familiarity with it.

The pilot data should include examples of all data types specified in the preliminary design. A common approach is to select a small but representative geographical area and to acquire all data for that area. The pilot products should also be representative of the final system, and include those considered by the users to be critical for the success of the system. If the choice between raster and vector data models is contentious, the pilot data and products must be selected to enable resolution of that issue.

The pilot study should yield valuable experience and user comments. These results may lead to refinement of the database and system specifications, and to review of the cost and benefit figures and the statements of intangible benefits, impacts, and risks.

Stage 2: Specification of requirements

In the second stage of the GIS acquisition model the results of the analysis of user requirements are developed into a specification against which proposals can be solicited and evaluated.

6. Final design

The objective of this step is to produce design documentation for inclusion in the request for proposals. Activities are:

- Finalize database specifications.
- Finalize functional specifications.
- Finalize performance specifications.
- Specify constraints.
- Specify generic system requirements.

The database functional and performance specifications are finalized by incorporating the results of the pilot study into the preliminary design document. The database specifications are required by vendors for designing their proposed systems. Functional requirements must be specified in detail and classified as either mandatory, desirable or optional. Only those requirements which are essential to the operation of the system should be specified as mandatory, as over-specification will make the evaluation of alternatives difficult and may result in the elimination of innovative proposals. Performance specifications should be stated in terms of the minimum acceptable performance (mandatory workloads), and optimum requirements.

Constraints which must be identified and specified may include existing hardware, software, communication systems, interface requirements and agency policies regarding compatibility and standards. Generic system requirements include maintenance, support, training, user and system documentation, development tools, upgrade paths, security and ergonomics.

7. Request for proposals

The request for proposals (RFP) document combines the final design with the contractual requirements of the agency. The RFP is then released to vendors. The activities are:

- Specify contractual requirements.
- Specify evaluation methodology.
- Release the RFP.

Contractual issues which must be addressed in the RFP include: the acceptability of multiple vendor solutions; the required maturity of proposed systems; provisions for special software development; how constraints must be addressed; general conditions of the proposal; and draft conditions of contract.

The optimum solution to a complex GIS requirement may involve multiple hardware and software vendors. The agency must specify whether it requires a primary contractor to coordinate and accept responsibility for the total project, or whether separate vendors may be contracted to implement parts of the system under the direction of agency staff. The primary contractor may be either the primary vendor or a company which specializes in system integration. Similarly, the RFP must state whether proposals must address the total requirement or whether proposals for discrete parts (such as hardware or data capture systems) will be considered.

The agency must also specify whether proposed solutions must be mature (fully operational), or whether systems currently under development will be considered. There are risks with both positions. Systems under development may appear to promise greater benefits than some operational systems, but there is a significant risk that they will not meet their time or performance specifications. The risk in eliminating such systems is that medium- to long-term potential benefits will be forgone. One intermediate approach is to nominate the benchmark testing date (Step 9) as the cut-off; only those functions which are demonstrable by that date will be considered in the evaluation.

Special software development may include customization of user interfaces, translation software for existing data, unique processing functions, and interfaces to other systems. The processes for developing and reviewing the software specification and design, and for monitoring the implementation, should be specified.

The design constraints identified in Step 6 may be stated in the RFP as mandatory requirements or, preferably, as issues to be addressed by vendors. The latter approach enables vendors to propose alternatives which they consider to be more cost effective than constrained solutions.

General conditions of the proposal will include the closing date, minimum information for a formal tender, conditions for variations to proposals during the evaluation period, and price basis. The RFP document requests vendors to respond to a large number of technical and contractual requirements. Vendors should be required to explain how their proposal complies with each mandatory, desirable and optional functional and performance requirement. They must also respond to every constraint and generic system requirement, and to the draft contractual conditions. The RFP should state that simple responses to complex technical requirements, such as 'complies' or 'understood', will disqualify the proposal from consideration as a formal tender. A useful approach is to include a questionnaire in the RFP which addresses the issues of most concern to the agency.

Draft conditions of contract (see Step 12) and the evaluation methodology to be employed by the agency should also be outlined in the RFP. The evaluation methodology would be a summary of the shortlisting, benchmark testing and cost-effectiveness evaluation processes (Steps 8–10), and a general description of the evaluation criteria to be used for each step.

Finally, the RFP is released to vendors by letter, advertisement or both. A minimum period of eight weeks should be allowed for vendors to prepare proposals for complex systems. A formal briefing may be provided to interested vendors during the release period.

Stage 3: Evaluation of alternatives

The third stage comprises three successive evaluations designed to identify which one of the proposed systems is the most appropriate for the agency. Boehm (1981) describes a number of performance and cost-effectiveness models which provide decision criteria for choosing between alternative computer systems. The approach described here employs shortlisting based on mandatory functionality and performance criteria, followed by a cost-effectiveness evaluation. Effectiveness is determined by benchmark testing and is quantified by a weighted sum analysis (Boehm's 'figure of merit').

8. Shortlisting

The objective of this step is to determine an initial shortlist of feasible systems by evaluating and scoring the information submitted by vendors. Activities are:

- Perform preliminary evaluation of proposals.
- Score functional requirements.
- Produce initial shortlist.

The preliminary evaluation of detailed proposals should identify any relationships between the proposals, and whether any should be rejected without further evaluation. Reasons for rejection at this early step may include clear failure to meet a mandatory functional requirement, inadequate detail in the response, unacceptable maturity, inability to form part of a total solution, and having costs which greatly exceed the alternatives and the projected budget.

Non-mandatory functional and generic system requirements are then scored from the vendor responses. Each requirement is assigned a weight and each is scored against a numerical scale (Boehm 1981). The weights should be determined in consultation with users, prior to receipt of the proposals. The experience gained during the pilot study should provide a basis for determining the relative importance of functions. Uncertain scores should be highlighted for special attention during benchmark testing. Discussions with other users will greatly assist the scoring of aspects such as the quality of maintenance and support.

The preliminary evaluation and scoring enable an initial shortlist to be produced. A maximum shortlist of five systems is recommended in order to keep the benchmark testing step manageable.

9. Benchmark testing

The objectives of benchmark testing are to confirm the scoring of functional requirements and to determine realistic estimates of performance in terms of workload. This step also enables an informal evaluation of the people behind the proposal. Benchmark testing activities are:

- Design the benchmark.
- Develop the benchmark data and documentation.
- Execute the benchmark.
- Analyse results.

The benchmark design must be based on the functional and performance requirements specified in the RFP. The design must establish the tasks to be performed, the data on which they will be performed and the output required. Guptill (1988) defines a comprehensive set of GIS benchmark tests, and Marble and Sen (1986) present a design for an application-independent benchmark for spatial database systems. Data to be used may include existing digital maps and attribute tables. Benchmark outputs may include measures of elapsed, CPU and operator times, together with products such as graphics and statistics. Other factors to be evaluated such as the user interface and system documentation should also be noted in the design document. Some vendors may be ambivalent about benchmarks because often the specifications are vague, the cost is out of proportion to the value of the potential contract, and insufficient time is allowed for preparation and completion (Reed 1988). These factors must be considered in the benchmark design.

The benchmark documentation should provide a general description of the tasks to be performed and a copy of the data to be used. Vendors must be able to prepare for the benchmark by loading existing data and ensuring that staff with the appropriate knowledge and expertise are available, but it is neither appropriate nor necessary to provide details of every task to be performed in advance.

Careful records must be kept during execution of the benchmark. The configuration, loading, and software version being used for the benchmark must be noted, in addition to the actual results. Structuring the benchmark design document as a proforma may assist this process. Evaluators must ensure that they understand what is being demonstrated and that all functions are being executed in real time.

The results of the benchmark tests will enable refinement of the functionality scores, and assessment of scores for workload performance. Proposals which prove unable to meet mandatory functional requirements, or which cannot achieve the minimum workload levels, are eliminated at this point.

Goodchild and Rizzo (1987) and Goodchild (1987) distinguish between what they call qualitative and quantitative benchmarks. The purpose of a qualitative benchmark is to determine the degree to which the proposed system can perform the required functions to the satisfaction of the benchmark team. They propose a scale of 'inhibition' to assess the degree to which a given function falls below an ideal performance, and thus inhibits the ability of the system to generate particular products which depend on the function. A quantitative benchmark is used to assess the degree to which the system can indeed perform the required workload within the constraints of personnel working time, available CPU cycles, peripheral devices, and storage capacity.

Each required function is exercised at least once during the benchmark test. Its qualitative performance is assessed by the benchmark team, and its resource utilization is recorded, along with various measures of problem size. These are then used to build predictive models of resource utilization by each function, so that workload can be estimated given the anticipated sizes of production problems. The result is a series of estimates of total resource utilization, which can be compared against the capacities of the proposed system. In one example (Goodchild 1987) the quantitative benchmark showed that the vendor had seriously overestimated the rates of digitizing which could be achieved in production, and also seriously over-configured the system's CPU.

10. Cost-effectiveness evaluation

Proposals which survive the initial shortlisting and benchmark testing steps are finally evaluated for their cost effectiveness. Activities are:

- Form notional configurations.
- Analyse costs for each configuration.
- Compute cost effectiveness ratios.
- Analyse results.

Notional configurations are formed by defining the hardware and software required. Some normalization of hardware, such as the volume of disk storage and number of workstations, may be necessary.

Capital and recurrent operating costs for these configurations over a nominal system life of at least five years are then determined. While only the cost differences are actually required for the purpose of evaluating alternative configurations, the total costs must also be determined to ensure that the original cost-benefit analysis remains valid. Schedules should be prepared showing capital and operating costs in each year, at both constant price and present value.

The cost-effectiveness ratio for each configuration is then computed by dividing the whole-of-life present-value cost by the functional and workload performance score, giving a cost per notional unit of performance. Because those systems which do not meet the required minimum levels of functionality and workload are not on the final shortlist, the ratios are actually a measure of the marginal increase in effectiveness that would be achieved with each surviving configuration.

While the configuration with the best cost-effectiveness ratio (lowest cost per unit of marginal performance) is in theory the optimum choice, it may not be affordable and there may be other factors not included in the evaluation which should also be considered. Other factors may include uncosted differences in the impact each configuration would have on the agency and staff, and concerns regarding the financial viability of vendors. The final report of the evaluation stage must therefore include, for each configuration on the final shortlist: the schedules of total costs (constant prices discounted to present value); the scores for non-mandatory functionality; performance and generic system requirements; a statement of relevant factors which are not included in the costs and scores; and a review of the original cost-benefit analysis.

Stage 4: Implementation of system

The final stage in the GIS acquisition model involves planning the implementation, contracting with the selected vendor or vendors, testing the delivered system, and actual implementation.

11. Implementation plan

The objectives of this step are to ensure smooth implementation and early delivery of benefits by developing a structured implementation plan. Implementation planning activities are:

- Identify priorities.
- Define and schedule tasks.
- Develop a resource budget and management plan.

The priorities for products and data should be reviewed in consultation with the end-product users to identify where early benefits can be achieved. The rationale is that a positive result early in the implementation, even if of modest proportions, will be more beneficial to the success of the GIS than a plan which does not deliver any tangible benefits to end-product users until late in the implementation.

Implementation tasks must then be defined and scheduled. Tasks may include: installation and acceptance testing (Step 13); customization of user interfaces; training of operators and support staff; initial data capture and product development; and medium- to long-term data capture and product development. Staff and cash budgets must then be linked to the schedule and management responsibility assigned.

12. Contract

This step involves integration of the agency's draft conditions of contract with the vendor's response and the implementation plan, to produce a legal contract. Activities are:

- Negotiate general contractual conditions.
- Negotiate special contractual conditions.

General contractual conditions include the contract period, payment schedule, reporting requirements, responsibilities of parties, insurance, warranty, indemnity, arbitration, and provisions for penalties and contract termination.

Special contractual conditions relate to the actual site and implementation plan. Reference must be made to the functionality and performance to be delivered. Other aspects are the processes and schedules for site preparation, delivery, installation, acceptance testing, training, support and maintenance. Procedures for the management of any special software developments must be defined, and the allocation of rights to such software must be stated.

13. Acceptance testing

The objective of this step is to ensure that the delivered GIS meets the contracted performance. Final payment should not be made until all tests have been satisfactorily completed. Activities are:

- Install the system.
- Test functionality.
- Test performance.
- Test reliability.

Installation may involve site preparation, establishment of communications systems, and development of special software and customized interfaces. The functionality and performance tests should be designed to ensure that the contracted specifications can be achieved under normal operating conditions.

Reliability refers to system availability and recovery, under both normal operating conditions and stress. The contract may specify an availability requirement in terms of the maximum down-time allowed per week to accommodate routine and emergency maintenance. Down-time should be closely monitored during acceptance testing. Recovery characteristics should be tested under all combinations of partial and total crash of both hardware and software.

14. Implementation

Activities in this final step are:

- Train users and support staff.
- Perform initial data capture and product development.
- Continue performance monitoring.

Training may be done in phases to build on the experience gained under operating conditions. The effectiveness of the training should be formally evaluated after each phase and the results reviewed in consultation with the vendor. The initial data capture and products should also be evaluated in consultation with the users and, if problems occur, the vendor.

Once the system is in routine operation, continuous performance monitoring should be introduced as a system management task. The performance data collected will help identify bottlenecks in the production process and enable system upgrades or procedure changes to be initiated.

MANAGEMENT OF THE ACQUISITION PROCESS

Organizational alternatives

The general model described above may be performed entirely by agency staff, entirely by external consultants reporting to agency management, or by some combination of agency staff and consultants. Issues which must be considered include the availability, expertise and cost of both in-house staff and consultants, and whether there are political advantages in utilizing consultants for certain steps. Appropriately qualified consultants will have no vested interest in the outcome of their work. This may be an important consideration for some users and for management.

GIS technology encompasses many disciplines and many people in various areas of an agency may be affected by its acquisition. Stakeholders in the acquisition are therefore numerous and diverse. Formation of a multidisciplinary project team, with either representatives from the affected areas or a clear brief to consult with them, is one approach to this diversity. Ideally, the team should contain members with expertise in the applications areas and in computing technology. The project team may undertake certain steps in the process, or be available to assist consultants as required.

Critical success factors

Information System (IS) failure may be defined as the 'inability of an IS to meet a specific stakeholder group's expectations' (Lyytinen and Hirschheim 1987). Expectations may have been explicitly stated in the form of technical specifications and budgets, or they may be unstated and relate to the values and perceptions of the stakeholders, in which case the evidence for failure is low system usage. Why then do some GIS implementations fail to meet expectations?

The Chorley Committee (Department of the Environment 1987) reviewed the UK GIS experience and Tomlinson (1987) reviewed that of North America. The Chorley Committee found that over-ambition, insufficient attention to user needs, conservatism of users, and over-optimistic estimates of data conversion and system development costs were the major causes of difficulties. Tomlinson (1987) considers that failures have been caused by poorly or undefined user needs, poor or no advice, attempts by some agencies to develop their own systems with inadequate resources and exaggerated goals, and a lack of motivation by users who were not involved in the acquisition process. Tomlinson concludes that the greatest obstacle is the human problem of introducing a new technology which requires not only a new way of doing things, but also has as its main purpose permitting the agency to do many things which it has not done before and often does not understand.

The Chorley Committee identified six factors which make an organizational environment conducive to the successful introduction of GIS: (1) geographical information is essential to operational efficiency; (2) the agency can afford some experimental work and trials; (3) a corporate approach to geographical information and a tradition of sharing and exchanging information; (4) a tradition of a multidisciplinary approach; (5) strong leadership and enthusiasm from management, with a group of enthusiasts at the working level; and (6) some experience of, and commitment to, information technology and the use of existing databases in digital form. The first and last largely reflect the nature of the agency's business, while the other four relate more to its corporate culture. If those cultural characteristics do not already exist, they will need to be developed to ensure that the GIS is a success.

CONCLUSION

The general model for the acquisition of GIS technology provides a framework within which agencies can undertake the analysis and specification of GIS requirements, the evaluation of alternative systems, and the implementation of the selected GIS. The GIS will be a success if the expectations of all stakeholder groups are met. While all of the steps in the model will contribute to this goal, two factors are regarded as critical: the user requirements analysis and the organizational impacts. The user requirements analysis must: (a) be thorough; (b) involve data capture, data processing and end-product users; (c) result in the users being committed to the system; and (d) be the focal point of the evaluation and implementation. The agency's staff must understand the organizational impacts of the acquisition and they must be committed to making the necessary changes.

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