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Choosing a GIS

T BERNHARDSEN

The process of selection and implementation of a GIS can take many forms, depending on the nature of the organisation, the scale of what is envisaged, and the criticality of the results to that organisation. In addition, there has been an evolution in the techniques used for selection of the GIS, away from the large scale specification studies carried out exhaustively before any call for bids is made towards an approach involving more interaction with the chosen supplier and more prototyping. This chapter describes 'best practice' and the pitfalls to avoid in choosing a GIS.

1 INTRODUCTION

The choice of a GIS is often a crucial one for an organisation and for those people who will use it. This is particularly true where there is little history of GIS in the organisation and its advent is seen as new 'empire building'. For the sake of the success of the organisation and for the career prospects of the individuals concerned, it is essential that the choice of the system be well-justified, transparent, and successful. This is not always achieved, for many choices need to be made.

1.1 Basic choices

Implementing GIS in an organisation calls for strategic decisions. This is because – whatever some vendors may say – a GIS facility cannot be bought 'off the shelf'. Rather it is an assemblage of hardware and software that becomes useful only when it is properly placed in an organisation and supported by expertise, structured data, and organisational routines.

When planning to introduce GIS, it is important to pay attention to all four links in the GIS chain, shown in Figure 1. The principal choices concern four aspects of GIS: data; hardware and software; expertise; and structuring. Precise definitions of each of these four aspects are often ambiguous and are usually interdependent. Moreover, they may change

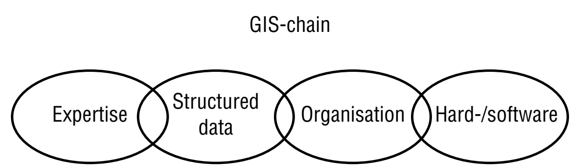

Fig 1. A GIS cannot be bought 'off the shelf'.

with time in ways that are difficult to predict. For these reasons, we will adopt a systematic approach to the selection of a GIS.

1.2 Phases in implementing a GIS

The process leading up to the implementation of a GIS usually comprises several steps. Consequently, major choices must be made considering all the relevant factors. The important decisions may take place at various stages of implementation and may be assessed and weighted differently according to current and future needs. But the same decisions are usually characteristic of different applications to a greater or lesser degree. Most major GIS projects traditionally include the following phases:

- assessment and evaluation of the status quo situation;
- development of a business concept;
- identification and specification of user requirements;

- identification and acquisition of data;
- cost–benefit analysis;
- devising a strategic plan;
- choice of hardware and software;
- defining and obtaining the necessary expertise;
- choosing a GIS supplier;
- system implementation;
- operation and maintenance of the system.

Some of these phases are sequential in that they naturally follow one another, some may be partly parallel, and others may be iterative. For instance, a cost–benefit analysis may trigger a re-evaluation of user requirements. Many other chapters in this book touch upon some aspects of these phases (e.g. see Obermeyer, Chapter 42, for a more detailed appraisal of cost–benefit analysis). More fundamentally, some of the phases are often iterative rather than discrete isolated stages. Indeed, recent experience from GIS projects shows that full implementation is sometimes more of a developing process than a pre-ordained step-by-step activity.

1.3 GIS impacts

The organisations which make choices about GIS may have widely varying starting points. For instance, many may already have access to a computer system including a network, as well as access to other systems which will need to communicate with any GIS. Some organisations may have digital georeferenced data available and possess some expertise in software, hardware, and GIS in general. Others may have minimal computer experience. Organisations in certain countries tend to choose final packaged solutions in preference to systems. In such cases, system integrators have become an important element in creating major systems using software, hardware, and data from different sources. An extreme solution is to out-source the whole operation for a longer or shorter period.

The scope of a GIS implementation project is proportional to the final impact of the GIS on an organisation – and vice versa. The impact may range from minimal to major, with no intervening sharp demarcation. GIS implemented in a small bureau of a large governmental agency may radically change that bureau. For the bureau, the impact is major; but for the parent agency, GIS is merely a tool which enables one of its many bureaux to accomplish its task. Conversely, a large agency in a small country might have to be reorganised completely in its conversion to GIS. In terms of equivalent efforts in larger countries, however, the effort involved may be small. Hence the qualifier 'from the users' viewpoint' might be applied to all assessments of the impact of implementing GIS. The bulk of the following discussion is devoted to the implementation of GIS in organisations for which it has a major impact.

1.4 Business concept and the definition of user requirements

A thoroughly-prepared business concept should form the basis for initiating GIS in an organisation. The motives for choosing GIS must be thoroughly understood. Only then can goals be identified with sufficient clarity as to become attainable. This obvious requirement often means limiting the overall scope of the GIS project.

The business concept forms the basis for defining tasks to be implemented by the organisation; and the user requirements are a consequence of these tasks. It is only possible to identify the requirements from the system once user tasks are identified and clearly understood. To solve the tasks set for them, the users need some data and information, some technical tools (hardware/software), expertise, and a suitable organisational structure. They need information derived from specified data plus applications which can make the data accessible, processable, and presentable. Expertise must be acquired for operating these tools and a suitable organisational structure formed to handle data flow and define responsibility for the different activities. Generally the bulk of user requirements will be associated with data and with different applications. Definition of user requirements is closely related to the development of the business concept and could form an integrated part in building that concept.

Traditional corporate GIS acquisitions for large organisations with operational responsibilities involved detailed specification of the user needs 'up front', often with the aid of a feasibility project. Increasingly, however, the greater part of work to define user needs actually takes place during and even after the system procurement is specified, as the first stage in the system's integration (see also Maguire, Chapter 25). This approach is mainly based on an increasing partnership between users and vendors; but, irrespective of whether identification of user needs is done pre- or post-procurement, it is a basic activity which should be treated in a structured way. Each organisation has to find the best balance between pre- and post-procurement in definition of user requirements.

1.4.1 'Up-front' definition of user requirements

Identification of user requirements in the pre-procurement phase should be based upon: user surveys; workshops; and a review of documented experience.

Thus user requirements for most corporate implementations of GIS in government and utilities are normally identified from user surveys, often as part of a feasibility study to establish the over-all potential for GIS in the business (see Meyers, Chapter 57). A standard questionnaire should be used in the user surveys to compile homogeneous information from varying sources and care should be taken in selecting representative respondents if the information gleaned is to be meaningful. In short, interviews with 'hands-on' users are often more productive than those with an organisation's senior executives. The interviews should be carried out by someone with broad GIS experience who can guide the respondents through the interviews. One difficulty with such surveys is that even the most experienced users seldom understand the full potential of a GIS facility. Consequently, user surveys are only valid at the time they are conducted and the results should be assessed and analysed by GIS experts who can more readily see the potential and the limitations.

Since enhancing GIS awareness is an ongoing process in the organisation, workshops could serve as a valuable means of speeding it up. Both workshops and user surveys could be carried out as integrated activities for identification of user requirements. Workshops could also be used as an approach to building a total business model for GIS, but business modelling for the sole purpose of GIS implementation is now relatively rare. Many organisations have already built such models as part of a wider programme and generic models are already available for sectors such as local government.

All organisations have their own particular requirements. But in most cases the experience of organisations with 'proven' facilities are the most valuable in defining user needs. The bulk of facilities now in operation comprise 'commercial off the shelf' (COTS) hardware and software (see Maguire, Chapter 25), but the realisation of user needs should be balanced against the attractions of newly available technology. Usually only a handful of organisations are able to remain at the forefront of the field: keeping abreast of the latest developments is very costly and special expertise is needed to deal with unproven approaches. It is not surprising therefore that 'no-one ever got fired for buying from IBM or Microsoft'! It is important, however, to balance this conservative tendency so, whenever GIS is to be implemented, a review should be carried out based on information from various sources including user experience from 'state of the art' facilities plus additional information from system suppliers and others familiar with the market and technological development.

Information compiled from user surveys, workshops, and reviews will normally lead to a long list of different user needs, all of which will have to be given a structured and neutral evaluation. The business model should form the basis for all evaluations – only requirements which are within the business model should be evaluated. (Indeed, this is one important reason for developing the business concept of the organisation.) Ideally, a ranking of needs should be based on a solid cost–benefit analysis or at least on an evaluation where costs and benefits have been taken into consideration (see Obermeyer, Chapter 42).

Consideration should also be given to what can be realised in practice within an acceptable time frame in respect of data capture, the building of expertise, and the creation of any necessary new structures within the organisation. The implementation period should be allowed for in the calculation of net present value in the total cost–benefit analysis, although this would have to be handled in a more pragmatic way for each individual requirement. The classic model (shown in Figure 2) is to identify user requirements as pre-procurement activity, and as part of a feasibility study, although it is becoming more usual to identify them post-procurement. The definition of user requirements should then be based on an intimate dialogue between user and system vendor, thus facilitating faster and smoother implementation.

1.4.2 The iterative approach to defining user requirements

The basic assumption for the bulk of the definition of user requirements being carried out as post-procurement activities is that the organisation has already selected a supplier of GIS software to develop applications which meet the business concept of the organisation. This will be done on the basis of responses from vendors to some relatively

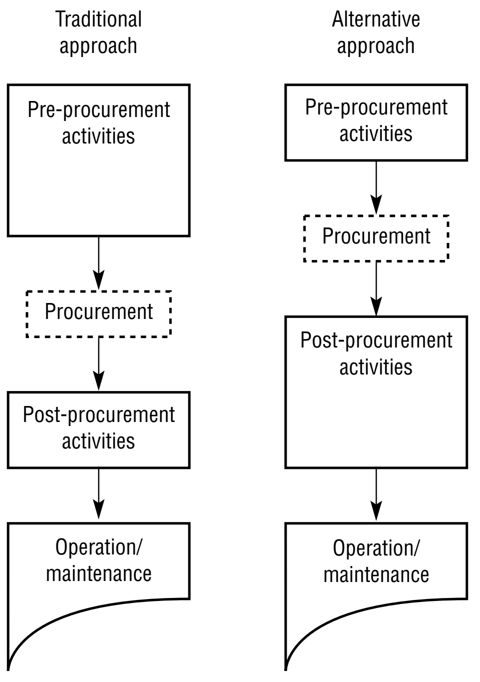

Fig 2. The classic model used to identify user requirements.

simple prior study. The requirements common to all such cases, irrespective of size or sector of the organisation, will constitute some form of design specifications. Though the terminology may vary, such design specifications normally comprise two parts – a specification of applications and a functional specification. The application specification sets out the organisation/user needs for GIS in terms of the applications required to be met, a logical data model, and the required service levels such as user numbers, user locations, requirements for availability, and other performance levels. As in the pre-requirements activity, user requirements may be identified through user surveys, workshops, and a review of experience from other users. The functional specification defines how the chosen GIS software will be implemented to meet these needs. It is usual for the suppliers to produce the functional specification, based on their intimate knowledge of the software.

The nature of the post-procurement activity varies according to the scale of implementation and the nature of the application, but user involvement should be relatively high since GIS technology is usually very end-user oriented.

2 ACQUIRING DATA FOR GIS

Data can be chosen once user tasks and needs have been identified and analysed. Choices of data are among the most important in implementing GIS as they largely dictate the costs and benefits of a GIS project. Experience indicates that data collection and maintenance accounts for 60 per cent to 80 per cent of the total cost in terms of time and money of a fully operational GIS. The benefit derived from a system depends on access to the right data at the right time, and on the efficiency with which the system processes the data accessed. It follows therefore that the choice of data should relate directly to user needs. In any event, it should be based on cost–benefit analysis (see Obermeyer, Chapter 42). The principal choices to be made in regard to data involve those of data model, data inventory, quality, coverage, and database design.

2.1 Data model

In an ideal world, data collected and entered in a database must be processed and arranged to provide information which is meaningful not only for current tasks but also for future tasks which are yet to be defined. Data must be organised before they can be useful. Clearly, then, data planning and structuring are essential to successful data use in GIS: almost all GIS projects should be carefully analysed in order to determine how the data are to be entered and organised.

The data model and its related structure must be independent of the software and hardware chosen. In many ways, the approach is the converse of selecting software and hardware to suit a data model. In computer science, data modelling is commonly regarded as part of the development of a data processing system. This view is common, but not always correct. All processed data must have initial sources and final uses and must relate to the real world outside the computer environment. A viable data model is part of the specification of a data processing system, not the result of it. Therefore the choice of data model should be made by professionals with experience in the field of applications involved, rather than computer scientists without experience of these applications. Figure 3 provides an illustrative data model for road information.

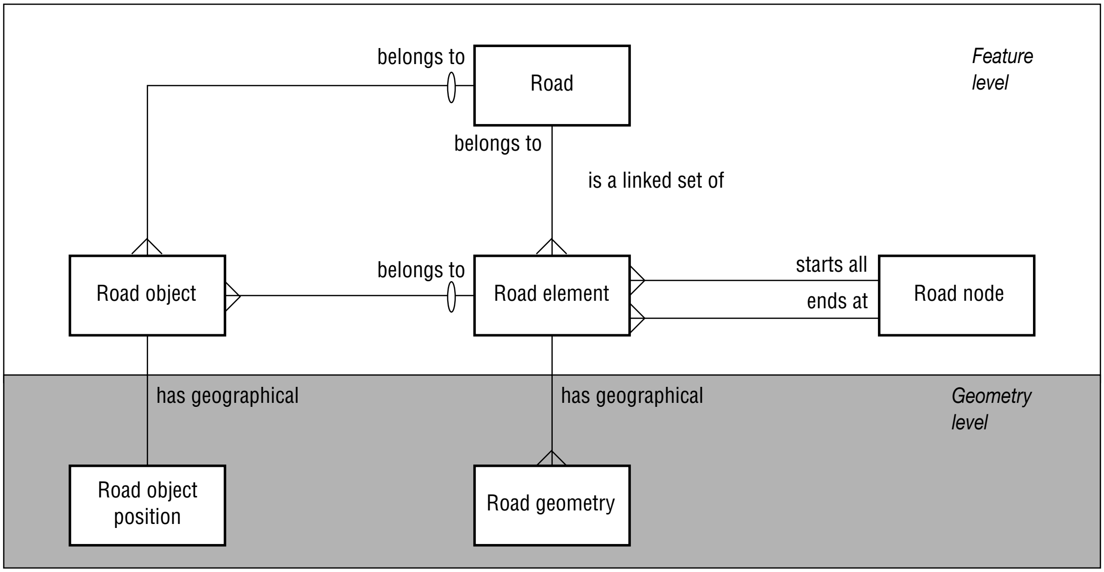

Fig 3. A data model for road information. Choosing proper data models is one of the sub-phases in choosing a GIS.

2.2 Data inventory

The definition of user needs and constraints will have identified a number of object types with their attendant attributes which need to be included if the business needs are to be met. Only relevant data should be entered in the database and the numbers of object types should be limited. Objective criteria must then be chosen to determine which objects are included. Here, cost–benefit analyses are usually a sensible starting point. In practice, however, the question is often the converse: how can the necessary data be acquired?

The chosen object types and their attributes must be formally described. Each type of object comprises a collection of individual entities to be treated identically, given names, and defined by object type and definition. Classes must be defined in order for the data to be classified. Relations between objects must also be defined before tasks can be addressed. Distinctions should be made between data shared by all users and data belonging to individual users or departments. Rules should be established to determine how objects are to be represented geometrically and to define the basic geometric elements to be used. In principle, the choice is between a vector representation (points, lines, areas) and a raster representation. The costs and ease of updating should also be considered. A good pragmatic rule is to enter no more data than can be maintained.

2.3 Data quality

Final data accuracy depends on the quality of the original input data and on the precision of the subsequent processing. Higher desired accuracy entails higher initial data quality and more precise processing, both of which increase system costs. Furthermore, the nature of requirements that data be up to date provide a further measure of data quality and hence system cost.

In general, choosing GIS data quality normally entails making a compromise between needs and costs. However, in practice the choice often reduces to shopping for what is currently available or can be acquired with little delay. In summary, four aspects of data acquisition comprise the criteria for selecting data quality: user needs, costs, accessibility, and available time frame: see Figure 4. The most meaningful measures of data quality are georeferencing accuracy, attribute data accuracy, logical relationship consistency, data completeness and data resolution, and data currency (see also Dowman, Chapter 31).

2.3.1 Georeferencing accuracy

The cost of using insufficiently accurate data may eventually be more than that of the original acquisition. In a worst-case scenario, the processed data may be useless.

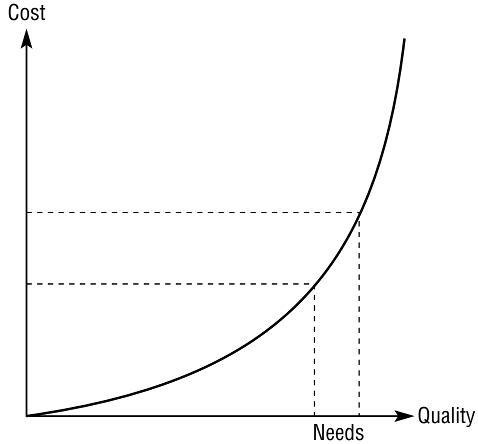

Fig 4. Quality affects costs, and the final level is normally selected in the balance between needs and costs.

Digital map data are often compiled by digitising 'ordinary' maps. This introduces several sources of inaccuracies, including those attributable to the original surveying, photogrammetric map making, map drawing, cartographic generalisation, and digitising. Storage of the digital data in single precision or double precision can also affect data accuracy whenever entries have many significant figures. All conversions from raster to vector presentations, and vice versa, entail some loss of accuracy. Errors can accumulate even as data are being processed.

Hence, choice of data sources (understanding the lineage of the data), acquisition methods, storage, and processing techniques all influence final accuracy. Clearly, only data sources and reduction techniques sufficiently accurate for user needs should be chosen. The opposite case, of sources and techniques constraining accuracy, should be avoided. All of this requires that those building systems understand not only the users' needs but also the detailed characteristics of the system components being used.

2.3.2 Attribute data accuracy

'Accuracy' is frequently understood to mean only that of geometric data although in practice the accuracies of attribute data are equally important. Operators encoding data may be unequally proficient and may therefore introduce errors. The methods used to collect attributes also influence their accuracies. Examples include collections based on statistical distribution hypotheses or other assumptions which fail to agree with the real world, as when observations are excessively scattered. An extreme case is when a cell size in a raster GIS is too coarse to register the phenomenon desired. Furthermore, measurement instruments may be improperly adjusted or calibrated, introducing systematic errors, or they may be subject to random inaccuracies, as for satellite sensors viewing reflected and re-emitted solar radiation (Estes and Loveland, Chapter 48). Errors can also accumulate when the data are processed, as in the case of geometric data.

As for geometric data, the choice of data source (lineage), acquisition methods, operator skill, and processing can influence data accuracy, but in practice, user accuracy requirements should dictate sources, qualifications, and techniques – and not the opposite.

2.3.3 Logical relationship consistency

The logical relationships in data must satisfy the requirements imposed on relationships between objects which, in turn, are based on the tasks to be performed. Thus roads must connect in a logical network, polygons must be closed, and so on (see Dowman, Chapter 31). Inferior topology complicates or introduces error in many GIS functions, not least in overlaying and network analysis. Consequently, data with unverified topology may well prove very expensive to the user through requiring much verification and correction or in terms of degraded quality of the final product.

Linking geometries and attributes correctly requires that the same identifier or ID codes are used in both sets of data. To preserve such comparability, spatial and attribute databases/sets should be updated simultaneously. If they are not, link inconsistencies may arise which will diminish the quality of the data jointly stored in the two databases. Thus, depending on the detailed user needs, operational routines and techniques must be chosen so as to preserve logical relationships as well as maintaining geometrical and attribute accuracies.

2.3.4 Data completeness and data resolution

Data completeness describes how completely data have been entered, such as whether attribute data as well as digital map data have been entered for all properties, all roads, and all buildings in an area. Completeness is of crucial importance for some objects. For instance, local or national statutes may require that neighbours be given notice whenever a property is divided. GIS may be used to locate those neighbours. Should just one neighbour be overlooked, an entire notification dataset may have to be recreated.

Completeness and resolution are often interrelated, so the observation density must be set such that it depicts all properties. Again, the operational routines and technologies must be chosen to satisfy user needs for data completeness and data resolution.

2.3.5 Data currency

The degree to which data must be up to date will depend on the object type and data application. Public works agencies often require the most recently available data on property boundaries, buildings, roads, and the like. Other data, such as for zoning boundaries, may change more slowly and simply (e.g. with only one agency capable of making the change); they thus require less frequent and simpler updating. However, attributes may change faster than geometries, such as in property data, where ownership changes more often than do boundaries. Currency of data becomes particularly significant whenever tasks involve data from various sources being combined.

The choice of how often data are updated has considerable effects on GIS. The more frequent the updating, the more effective the GIS is liable to be, but also the greater its cost. Consequently, the choice of update frequency depends on anticipated costs and benefits. Again, this underscores the principle that data should be entered into the GIS only if they can be kept up to date at reasonable cost.

2.4 Geographical coverage

As a rule, the basic decision to be made on the geographical coverage of a GIS is whether to provide full digital coverage of all regions and areas or to digitise full information only for areas which are more active and hence more rapidly changing. Again, cost–benefit evaluations are the best guide to decision-making. Different user organisations may have different needs for the geographical coverage of digital information. The distinctions involved are often dictated by functional or administrative divisions, such as townships, regions, counties, or entire countries. But for a commercial GIS user, the driver may be those areas which offer greater market returns, perhaps because of their greater populations or greater rate of change. In general, a need for digital geographical coverage must be fulfilled completely before the bulk of user benefits accrue. This is because incremental system development invariably includes periods when both conventional and digital data are used in parallel and this usually increases the work entailed in producing a given final product.

2.5 Database design

Meticulous database design is essential both in realising the functions required and in delineating the scope of the GIS. The design parameters must include the entry of relevant data, the ease of access to data, the efficiency with which functions are executed, the facility with which data are updated, the system's receptiveness to new types of data, and the ease of restructuring data already in the database.

The data models chosen provide the basis for the database design and thereby influence the choice of hardware and software. But the system software and hardware chosen also influence the detailed design of a database (see below). Distributed database designs for networks should in principle be based on the organisation of access tasks, but the characteristics of pre-existing computer systems within the organisation can clearly constrain design. The best approach is for each organisation to choose databases best suited to its needs and to incorporate direct or indirect interorganisation communications via network and jointly available databases where necessary. Even so, this may only ameliorate the problems: for example, in most GIS, data are organised in tiles and thematic layers and these may differ between systems. In general, such geographical storage structures should be chosen carefully since established database structures are difficult to modify.

3 CHOOSING HARDWARE AND SOFTWARE FOR GIS

The right choice of computer hardware and software is essential. In practice, this may prove both easy and difficult. The choice is easy in the sense that it deals with comprehensible details such as technical characteristics and prices which may be compared. Yet it is also difficult because future applications are unknown and computer technologies change continuously. The impact of implementing GIS in an organisation is uncertain and the pressure from competing system vendors, who typically market aggressively, also complicates choice.

3.1 Pilot project

A pilot project can provide a sound basis for choice of user functions, data, equipment, software, training, and structuring (see also Maguire, Chapter 25). A pilot project should be set up to: test various production methods; test the functionality of different types of equipment; identify system faults; test applications; test data transfer; and test system integration.

The scope of a pilot project depends on the complexity of the organisation and of the system. But in any event, the project scope should be held within reasonable limits in terms of time, budget, staff involved, geographical coverage, and volume of thematic data involved. The results of such a pilot project should then be assessed before any further steps are taken. This should be treated as a milestone in any project plan and one after which the whole project can still be abandoned if necessary.

3.2 Purchasing rules

Major purchases of hardware and software may be subject to rules or guidelines, especially where the purchases are made by larger corporations or in the public sector. Today, international agreements also govern major public agency purchasing of hardware and software. Economic agreements also govern public sector purchasing, such as the World Trade Organisation's (WTO, formerly GATT) Public Government Procurement Agreement of 15 April 1994 and the regulations agreed within the European Economic Area (EEA) by Directives of Public Procurement Nos 93–96. Rules are often linked to stipulated cost levels so that a rule comes into effect when total cost exceeds a set amount.

Specific cost limits apply for different product sectors in the EEA, such as goods and service, building and work, supplies and communication etc. At the time of writing (early 1997), the limit for public sector procurement at the municipal level for IT goods and services which do not go through a full, publicly advertised procurement carried out to EEA rules is ECU 200 000 (or some US$ 230 000). The corresponding limit for central government procurements is lower, ECU 140 000 or US$160 000. Procurement notices have to be published throughout the EEA for purchases in excess of these limits and strict rules followed; failure to do so is likely to lead to punitive sanctions. It is worth noting that these limits apply to the total contract value and, to a certain extent, to total purchases within one product sector. Regulations are quite strict with regard to splitting any procurement into several smaller contracts. In the case of a contract which extends over a number of years and involves several sub-contracts, individual procurement notices may be required for each supply. It should be obvious that familiarity with all such rules is a prerequisite to purchasing, especially if the purchase is to proceed without undue delay.

3.3 Organisation of the selection and implementation process

An organisation or purchaser should clearly define its own role before requests for proposals are sent to vendors. The assignment of responsibility for the selection and implementation process normally varies considerably, depending upon the competence of the organisation involved and the nature of the market supplying goods and services. In general, an organisation elects either to retain responsibility for a system implementation itself or to assign it to others. There are many mixes of these two main approaches. The organisation, or a consultant it engages, can design the detail of the system and issue specifications for equipment, sub-systems, and the like. The organisation itself is then ultimately responsible for the system(s) being able to fulfil the design requirements. Most organisations prefer to issue design requirements and invite suppliers to respond with bids which include the detailed specifications of how the requirements are to be met. The chosen supplier(s) then carry the ultimate responsibility for the system(s) being able to fulfil the design requirements.

3.4 Design requirement and system specifications

The specifications of the final requirement are usually set as part of the compiling of a request for proposal, which aims to provide potential vendors with adequate information for bidding. A comprehensive request for proposal is an essential basis for good bids.

The design requirements of a system stipulate how it should function, not how it should be implemented. In most cases – as indicated earlier – the design requirements are based on an appraisal of the current situation, the results of user surveys, cost–benefit analyses, strategic planning, a pilot project, a review of existing technologies, and compromises based on market choices. Requirement specifications fulfil several functions. First and foremost, a requirement specification tells bidders what kind of applications a customer wants. But it also acts to enhance in-house understanding of the system to be purchased. Finally, it serves as the gauge against which compliance to contract is measured.

Normally, requirements vary considerably in their importance. So they can be grouped, for example according to: requirements which must be fulfilled (mandatory); requirements which may be fulfilled; future requirements which shall or may be fulfilled when the technology becomes available; and requirements which are secondary or optional, on which the vendor may choose not to bid. Cost–benefit analyses may be used to rank the importance of the different requirements.

Design requirements can conveniently be subdivided into main requirements and special requirements. The reasons and goals for implementing GIS should be stated. The tasks to be addressed in the organisation and the envisaged future functionality of GIS should be identified, such as in stipulating whether the system shall process vector data, raster data, or both. Data security may also be a factor that must be described.

The functional requirements vary from organisation to organisation. Typical requirements include: a description of the different applications; data conversion, which will depend on the types of data processed, the technologies employed in data conversion (scanner, digitiser), and the volume of data to be converted; functions for importing and exporting data, including formats; database designs and storage functions, which depend on factors such as the data models to be preserved and the data volumes to be stored; and printout and presentation of data, for example to meet specified standards.

Another example of a key function to be specified is that of search functions, together with search criteria and search speeds. Analytical functions are often needed for overlays and in network analyses. Data integration may be an important issue: many organisations already have systems, such as client lists, property registers, pipe network descriptions, and operation and maintenance systems, which should be integrated with GIS. In such cases, the degree of integration must be described. However, in practice, experience to date indicates that overly-ambitious integration plans may well degrade a GIS project which is otherwise viable. The functions of standard operations, such as customer 'front desk' services and print-outs, may also be described. The data used by all sub-systems will need to be updated, so updating functions must be described and be mandated to be consistent and synchronous across the entire system. Other facilities may require special functions, such as for geometrical design and for the computations of lengths, areas, volumes, and other parameters. In all cases, there should be a clear statement of how vendors shall respond to requirements which their systems do not currently meet but which they propose to develop.

As mentioned above, most organisations considering implementing or updating GIS already have some more or less advanced computer system(s). It follows therefore that existing computer systems must be described in the specification to ensure compatibility of the new equipment and software. The descriptions should include type and capacity of equipment (storage, processing speed, number of work stations, and so on), type of operating system, and other relevant software.

Many organisations have an overall information technology strategy which will govern some aspects at least of a new GIS installation. The factors involved include mandated operating systems, hardware platforms, networks, etc. In addition to this enterprise-wide information technology strategy, special requirements may be stated for a GIS facility such as for user interfaces and response times. The number of workstations and numbers and types of peripherals incorporated in the GIS facility must be stated. The chief parameters of the system configuration and attendant network design must also be listed. Normally, however, the details of a new system are not described in great detail because technology changes so rapidly. Vendors should be encouraged to offer new technologies and to describe them in terms of the benefits they will provide for the applications involved. Finally, the invitation to bid should also include a description of the requirements for documentation and training and an installation schedule should be stipulated.

3.5 Invitations to tender

A well-prepared invitation to tender, based on the design requirements, is a prerequisite to meaningful proposals. Evaluation of responses can be simplified by compiling part of the invitation to bid as a list of questions, to which bidders respond. This is a form of compliance list, in which the response to a question is 'comply' or 'not comply'.

Such a request for proposal should include a description of how a bid should be structured and specify which criteria will be used in assessing it. For instance, the importance of fulfilling the functional and technical requirements in relation to price, the size and stability of the bidder, the support and training, and the documentation offered may be described. The procedures for handling queries from vendors and other relevant information during bidding should be described. For instance, responses to all questions from any one bidder may be copied to all bidders. An invitation to bid should be sent to no more than three or four selected vendors, who are expected to be able to meet the requirements and the need for support.

3.6 System evaluation

System proposals should be evaluated in terms of how closely the bids meet the requirements stated in the request for proposal and on the quality of the vendors that are bidding. Several objective parameters may be drawn upon to simplify choices and aid decisions. In any event, requirements should reflect user needs, not just system parameters. Systems may be numerically ranked by assigning weighted values to all selection criteria. The weighted sums for all systems can then be ranked. Functions not available but offered as developable must be assessed separately.

Often requirements may be met not by a single system but by a combination of several systems. Choosing a new system that will include integration with existing systems can complicate the situation. Criteria for determining the final choice of vendors usually includes service capability, market position, company stability, price policy, and references from satisfied customers. The bottom line is that both a system and its vendor are chosen.

The fulfilment of functional requirements may conveniently be assessed separately, before the bid prices are compared. This prevents unconscious favouring of the system bid at the lowest price. Normally, no one system bid is superior in all aspects. Consequently, and as stated in Aronoff (1989), the final choice often involves compromises: see Table 1.

3.6.1 Benchmark testing

The performance of a system as installed is crucial to meeting the business case. The performance of a system at some future date is of lesser immediate interest. Performance may be assessed in terms of how a system executes specific functions, how rapidly it works, how simple it is for users to operate, and how flexible it is in current applications. Such questions are best answered by testing. Different systems are best compared by running specific test programs using uniform test data. This benchmark approach, or functional test, is valuable in assessing different systems and approaches. Each system should be tested intensively over a few days.

Table 1 Typical comparison of four GIS (*a*, *b*, *c*, and *d*), using an initial ranking of 1 through 10 and then weightings of 1 through 5.

		Rank				*Weighted rank*			
Selection criteria	*Weight*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Human–machine interface	5	6	7	8	7	30	35	40	35
Equipment functionality	3	8	6	7	6	24	18	21	18
Drawing functions	2	9	8	7	7	18	16	14	14
Own programming	3	7	5	5	6	21	15	15	18
Database design	4	7	6	6	8	28	24	24	32
Data interchange	5	5	7	6	7	25	35	30	35
Expansion possibilities	4	7	8	8	8	28	32	32	32
Documentation	4	7	6	6	5	28	24	24	20
Follow up	4	7	9	9	6	28	36	36	24
Unweighted sum		63	62	62	60				
Weighted sum						230	235	236	228
Total rank		1	2	2	4	3	2	1	4
Price rank						3	2	4	1

3.6.2 Contract

A mutually acceptable, clear, and complete contract is essential and benefits both purchaser and vendor. For a complete system, two contracts should be entered, one for purchase and one for maintenance. The purchase agreement should contain a short description of its scope and the manner of payment. Normally, the delivery will have a guarantee period, so the goods and services supplied under guarantee shall be specified. Joint activities and responsibilities may be described as needed. The contract should contain guidelines for confidentiality between the contracting parties and how ownership (hardware) and use rights (software) are to be transferred to the purchaser and any successor bodies. The treatment of delivery delays must be specified as must the handling of any breach of contract. A maintenance agreement should contain a description of its scope and of the services to be supplied for its duration. It should contain statements of compensation arrangements, payment conditions, and handling of any breaches of contract.

3.6.3 The final decision

The final decision to procure a GIS should be made only after contract negotiations have been successfully completed and all financial and legal aspects have been clarified. Careful specification, bid evaluation, and contracting procedures, as discussed above, ensure achievement of a good decision. But only future use will determine whether the right choices have been made!

3.6.4 When a system has been chosen

The vendor should fulfil the contract concerning: installation/integration; customisation/development, etc.; and acceptance testing. Acceptance testing may be necessary to determine whether a system functions as assumed, and conforms to contract specification.

4 CHOOSING GIS COMPETENCE

As discussed above, the fundamental choices involved in implementing GIS are associated with data, hardware and software, expertise, and structuring. Many GIS projects, particularly those in the public sector, suffer from lack of training of operators and users. Personnel management for the transition to a new technology should therefore be given top priority.

The question reduces to the type and level of expertise to be obtained and maintained in the organisation. In turn, the expertise, still to be attained depends on its level at the outset and on how a project will be staffed, as well as on whether external services are to be involved. Ideally, all staff members who have direct or indirect contact with GIS or its products should be suitably trained. This also applies to executives, who should have a general understanding of the potential and the limitations of GIS as a tool in decision-making. Middle managers should have an adequate technical background to coordinate the implementation of GIS. Field staff and others who acquire data should be trained in its conversion and updating. Usually, GIS software system managers and operators need to be thoroughly trained.

Most organisations elect to retrain their own personnel in conversion courses instead of hiring outside expertise. Training should comprise on-the-job training as well as formal education (see Forer and Unwin, Chapter 54). As discussed above, the needs for expertise are often underestimated. Without the requisite expertise, progress can be frustratingly slow. Consequently, maintaining and building staff expertise should be a top priority task.

5 ORGANISATIONAL STRUCTURE

The efficient exploitation of a new technology in an organisation often requires that work routines and chains of command be altered. In turn, the overall organisation is affected. In practice, altering an organisational structure may be difficult, both because some elements of its structure are intangible and hence difficult to define, and because invariably there are both formal and informal positions in all chains of command. Altered work routines entail organisational changes. Changing the organisation changes staff authorities and relationships (see Campbell, Chapter 44). Staff changes always introduce human factors that are difficult to predict or control.

Consequently, organisational matters are vital in all initial implementations of GIS facilities. The organisational problems are often more complex and more crucial to success than are the technical problems. Changing and replacing staff members is less straightforward than changing computers and may trigger unanticipated difficulties. Hence, organisational matters usually require more consistent management involvement than do technical problems.

Some organisational choices must be made at a very early stage. The design of the system, system configuration, and network are all influenced by how updating is organised. So updating routines must be outlined during the compiling of the request for proposal. New staff positions must be described, complete with delineations of tasks, duties, and responsibilities. In principle, new tasks and new data flows may be chosen independently of the people, groups, or departments ultimately responsible for them. So new staff structures must be defined, and management modified accordingly.

In practice, GIS implementation projects are often understaffed. Therefore, staff requirements should be carefully assessed at the outset and the staff skills identified must be made available to the project. As a rule, this usually requires either that staff members be relieved of their customary tasks and assigned to the project, or that personnel be hired specifically for the project.

A strong, independent project-based organisation is essential to the success of any major GIS implementation. The project team need not be permanent: it can be disbanded when the GIS facility becomes operational. Prudent structuring or restructuring of the organisation should prevent undesirable monopolisation of information. Such restructuring should be tested before being finally implemented. Long-term changes may be made after the initial operational phase of a new GIS facility, as stressed in Medyckyj-Scott and Hearnshaw (1993).

6 FINAL REMARKS

With time, most GIS users discover new needs and therefore new applications for systems and data. The new applications often differ considerably from those originally anticipated for the facility and therefore are among the factors that increase the ultimate benefits which the GIS provides. The procedure for assessing new applications is straightforward. After a GIS facility has been in operation for a few years, a survey of user needs may be made to chart new needs. New needs identified may be evaluated in terms of benefit-to-cost ratios, just as were the needs for which the system was originally designed. Likewise, needs for restructuring the system or the organisation should be evaluated and, if need be, enacted using the same criteria as used initially.

Choosing a GIS can often be a frustrating process as the decision-making processes entail many uncertainties. But the pay-off can be considerable: the anticipated longevities of the different components of a GIS facility are:

Computer equipment	2 to 5 years
Software	3 to 8 years
Data	10 to 50 years and more

A GIS facility is thus rarely a once only, short-term investment. In a professionally-planned project, the relatively short lifetime of hardware and software need to be reflected in the budget by the allocation of funds for long-term maintenance and renewal. Without planning for and continuing investment in the long-term, most GIS will soon become relics. Nothing is more useless than speedy provision of very out-of-date information.

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