

Applications of Geographical Information Systems (GIS) for Spatial Decision Support in Eco-Tourism Development

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Abstract: Geographical Information Systems (GIS) are becoming an increasingly integral component of natural resource management activities worldwide. However, despite some indication that these tools are receiving attention within the tourism industry, their deployment for spatial decision support in this domain continues to be very slow. This situation is attributable to a number of constraints including a lack of appreciation of the technology, limited understanding of GIS principles and associated methodology and inadequate organizational commitment to ensure continuity of these spatial decision support tools. This study analyzes these constraints in depth and includes reviews of basic GIS terminology, methodology that could be used in ecotourism development. The GIS terminology addresses the two fundamental types of GIS (raster and vector) and discusses aspects related to the visualization of outcomes. With regard to GIS methodology, the argument is made for close involvement of end users, subject matter specialists and analysts in all projects. A user-driven framework, which involves seven phases, to support this process is presented together with details of the degree of involvement of each category of personnel, associated activities and analytical procedures.

Key words: GIS, tourism industry, eco-tourism, development, analytic, personnel, activities

INTRODUCTION

The current tourism industry can improve its competitiveness, by utilising the emerging Information Technology (IT) and innovative management methods. The IT and telecommunication world are showing great expectations for the opportunities offered by the development of new and sophisticated services, with increasing levels of interactivity, covering heterogeneous areas like entertainment, commercial tourism, information and education (Di Concetto *et al.*, 1999). In addition, they could also foster international trade and regional co-operation and create more jobs. In an age when information empowers the possessor, countries lacking of it might be devastated by poverty, hunger, disease and political instability. Ultimately, these technologies may also jeopardise the sovereignty, security, human rights and consequently sustainable development (Domatob *et al.*, 1996).

GIS are increasingly used in ecological areas to record baseline information about the state of the areas and the stresses affecting them; assess methods for

monitoring sustainable development and evaluate scenarios deriving from the interaction of biophysical and social processes. This information provides essential inputs to decision making at all levels from the local to the global. There are many problems and challenges in applying the essentially two-dimensional technology of GIS to three-dimensional mountain environments (Price and Heywood, 1994). GIS technologies are also being used in tourism planning, coastal tourism and recreation world wide (Mutch, 1995).

Ecotourism interests can also convince local people that their resources are as, if not more, valuable when intact than when extracted from the ecosystem. When a user fee or visitor admission fee structure is imposed, real economic incentives for protected areas can catalyse their formulation (Agardy, 1993). Ecotourism hopes to change the unequal relationships of conventional tourism, thus it encourages the use of indigenous guides and local products. It claims to combine environmental education with minimal travel comforts, help protect local flora and fauna and provide local people with economic incentives to safeguard their environment.

This situation is analogous to the need for monitoring existing operations in terms of environmental and/or other impacts. As noted by Osleeb and Kahn (1998), these decision support needs cannot be effectively addressed without the use of GIS.

Kapetsky and Travaglia (1995) also point out that the individual investor interested in ecotourism alongside aquaculture development also requires spatial information particularly at the time of site selection from among a range of alternative locations with different biophysical and socio-economic characteristics. GIS is potentially a powerful tool for assisting this class of decision-makers and is already being effectively used for such purposes in some places (LUCO, 1998), where advanced capabilities in terms of infrastructure and trained personnel exist. In general, however increased deployment of GIS for practical decision making in ecotourism is hampered by several constraints including: appreciation of the benefits of such systems on the part of key decision-makers, limited understanding about GIS principles and associated methodology, inadequate administrative support to ensure GIS continuity among organizations and poor levels of interaction among GIS analysts, subject matter specialists and end users of the technology (Kapetsky and Travaglia, 1995).

The primary goals of this overview are to examine the above constraints in depth, which includes an introduction to GIS terminology and methodology, topics that are relatively well documented in the literature (Burrough, 1986) but to which personnel in the tourism industry have had limited exposure, especially from the perspective of GIS as a tool for practical decision-making.

MATERIALS AND METHODS

The materials used for this study are mainly secondary, which were sourced from the internet, journal articles and textbooks. The method of study involved an extensive review of literatures on the use of GIS on spatial decision support in relation to how the tool GIS is being applied in the tourism industry.

RESULTS AND DISCUSSION

GIS terminology: GIS is an integrated assembly of computer hardware, software, geographic data and personnel designed to efficiently acquire, store, manipulate, retrieve, analyze, display and report all forms of geographically referenced information geared towards a particular set of purposes (Burrough, 1986; Kapetsky and Travaglia, 1995). An excellent introduction to GIS terminology, maintained by the Association of

Geographic Information. There are essentially two types of GIS-vector and raster systems. These systems differ in the manner by which spatial data are represented and stored.

Burrough (1986) and Meaden and Kapetsky (1991) provide useful comparisons of vector and raster systems in summary form. In both systems, a 'geographic coordinate system' is used to represent space. Many coordinate systems have been defined, ranging from simple Cartesian X-Y grids to spatial representations that correspond to the real world such as latitude/longitude pairings, State Plane coordinates or the Universal Transverse Mercator coordinate system (Burrough, 1986; Thompson, 1998).

Vector GIS: In vector GIS, spatial data are defined and represented as points, lines or polygons. A point is defined by a single set of coordinates. Examples of point data for ecotourism applications may include features or spots for recreation such as beach, rest houses, etc. locations. Features such as roads, rivers and canals are conveniently represented as lines. Lines have starting and ending points referred to as nodes, which may include a large number of vertices. The segment of a line between two vertices is referred to as an arc. Polygons are used in GIS to represent enclosed areas. A polygon consists of a number of lines but is distinguished by the characteristic that its starting and ending nodes are the same. For ecotourism applications, examples of polygons include forest, streams or pond, lakes and distinct type of land classification (e.g., mangrove forest, rain forest). Based on the coordinate system used, a vector GIS knows where the spatial feature (point, line or polygon) exists (i.e., its absolute location) and its relationship to other features (topology or relative location). After spatial features are represented in vector GIS, their associated properties can be specified in a separate database. Vector GIS lend themselves well to the use of relational databases because once the spatial features are specified (once), any amount of related data can be associated with them. The term coverage is used in the GIS literature to refer to the combination of a geographically referenced feature and its associated data. Thus, a road network would refer to the line in a vector GIS that represents its route and the associated data such as volume of traffic, directions, quality and characteristics of roads and possibly spatial locations for different uses that could serve the needs of the tourist.

Raster GIS: In a raster GIS, space is represented by a uniform grid, each cell of which is assigned a unique descriptor depending on the coordinate system used.

Thus, a cell in a grid that uses the latitude/longitude system would have a pair of coordinates. Numerical data pertaining to spatial features that are represented in the grid are assigned to the appropriate cell. Raster GIS can be conveniently thought of as being a spreadsheet. In raster systems, georeferenced data stored in a grid constitute a layer, as opposed to coverage in vector systems. Each grid contains a unique set of information. In other words, there would be as many layers as there are properties of the spatial feature such as layer containing rivers, roads, forest, buildings, infrastructures and facilities when creating database for ecotourism development. Consequently, data storage requirements for raster GIS are generally higher than comparable vector systems.

Further, if there is a need to integrate different layers that describe a certain feature, the process may also be more costly in terms of access time. These disadvantages are perhaps less important in present day computers because large hard disks are not only relatively inexpensive but also allow rapid data retrieval. A more important disadvantage of raster GIS is that the spatial resolution of analyses is limited to the cell size of the coarsest layer. When the cell size is large relative to the scale of analysis, maps created from raster data tend to be somewhat blotchy. Nevertheless, raster systems are particularly useful when it comes to numerical manipulations because of the uniform grid structure. For instance, they lend themselves well to spatial modelling applications. As an example, a water temperature simulation model can be executed with weather datasets (e.g., air temperature, solar radiation, cloud cover, relative humidity and wind speed) in the form of raster inputs which could provide useful information for tourism participation. Model output can be exported to a gridded file, which in turn can be imported into raster systems for further classification and display (Kapetsky and Nath, 1997). Another advantage of raster GIS is that remote sensed data (which are usually stored in raster format) can often be directly imported into the software and immediately become available for use (Burrough, 1986).

Analytical scope, reporting and visualization: One of the powerful features of both vector and raster GIS packages is that statistical summaries of layers/coverage, model stages or outcomes can easily be obtained. Statistical data can include area, perimeter and other quantitative estimates, including reports of variance and comparison among images. A further powerful analytical tool that aids understanding of outcomes is visualization of outcomes through graphical representation in the form of 2 and 3D

maps. For example, entire landscapes and the ecosystem can be viewed in three dimensions, which is very valuable in terms of evaluating spatial impacts of alternative decisions in ecotourism planning and management.

Techniques have also been developed to integrate GIS with additional tools such as group support systems that allow interactive scenario development and evaluation and support communication among stakeholders via a Local Area Network (LAN) (Faber *et al.*, 1997). There is also currently rapid development and deployment of Internet-enabled GIS tools, which allow a wider community of decision makers to have instant access to spatial data. All of these tools are constantly being added to GIS packages and are of great value if appropriately used. Presently available tools include Arc: Explorer and Internet Map Server (from ESRI, Inc) and Map Xtreme (from Map Info Corporation). Guidelines for selecting GIS tools are available by Burrough (1986), Meaden and Kapetsky (1991) and Burrough and McDonnell (1998).

GIS methodology: Ideally, any GIS study will consist of seven phases: identifying project requirements, formulating specifications, developing the analytical framework, locating data sources, organizing and manipulating data for input, analyzing data and verifying outcomes and evaluating outputs (Fig. 1). In practice, it may be necessary to iterate within the overall process, particularly among the first four phases. The Fig. 1 also indicates the degree to which different types of project personnel namely end users, subject matter experts and GIS analysts can be expected to be involved.

The degree of personnel involvement within each phase will vary according to the organization(s) and/or types of personnel, as well as according to the requirements of specific projects. With regard to the first phase of any GIS project (basically a conceptualization and planning step that precedes actual implementation), our opinion is that it has traditionally been somewhat neglected both in the GIS literature as well as in practice. This is true despite the fact that it will likely determine the extent to which information generated by the use of GIS is used in real world decision making. The latter criterion, of course, is the ultimate yardstick by which success of spatial methods and technology will be measured over the long-term. The phases involved in any GIS study (Fig. 1) described occur iteratively in the sense that project personnel may often conduct a pilot-scale study.

Figure 1 shows the phases in a GIS project. In practice, most of the iteration within the overall process is to be found within the first four phases. Involvement of

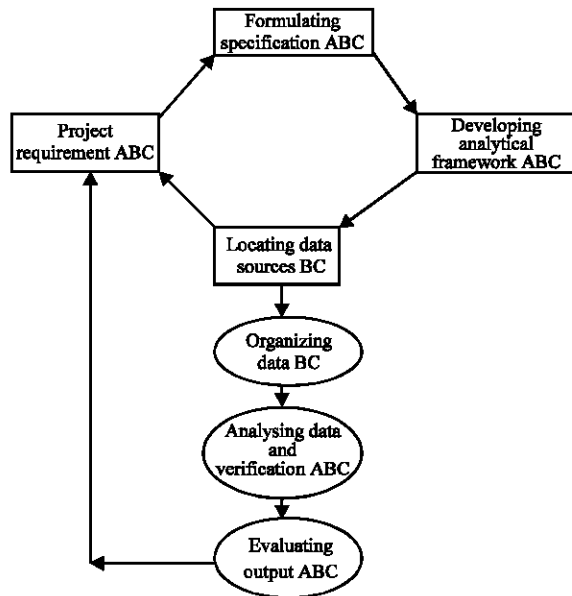


Fig. 1: Schematic representation of the phases in a GIS project. A = involvement of end users, B = subject matter specialists and C = GIS analysts; within each of the phases is also indicated among the symbol, sizes reflecting the importance of the respective role played by each group

end users (A), subject matter specialists (B) and GIS analysts (C) within each of the phases is also indicated, with symbol sizes reflecting the importance of their respective roles with available information and then successively enhance and/or refine the analysis until a satisfactory end point is reached. Alternately, subsequent phases in the project cycle may result in new information that needs to be incorporated in the preceding phase(s). For example, it may become evident during the development of the analytical framework that requirements documented during the first iteration of the project cycle (Fig. 1) may need to be revised.

Once project personnel explicitly recognize that GIS work is iterative in nature and begin to document what is learnt during each phase, it becomes easier to track how user requirements are explicitly addressed during implementation (often referred to as traceability in the software literature; Ambler, 1998) and to deliver timely as well as meaningful project updates (e.g., GIS outputs and reports).

Identifying project requirements: The process of identifying requirements for a GIS is essentially a multiple stakeholder decision-making situation. This is because such work is invariably executed by a group of subject

matter experts and analysts and because results of the analyses are potentially useful to a range of decision makers. Individuals in these three broad groups of stakeholders are likely to have different perspectives and expectations with regard to the capabilities and limitations of GIS. It is important that these perspectives and expectations are allowed to surface during the early stages of GIS work so that an enabling environment can be created within which decision support needs of end users are discussed and project goals formulated.

The observations are consistent with the research by Campbell (1994) and Campbell and Masser (1995), who suggest that the factors are important in successful GIS implementation and its subsequent use in decision making: an information management strategy in which the needs of users are clarified and resources and values of the organization(s) are accounted for. The fundamental message here is that if end users are involved early on in the planning process for GIS projects and their needs better understood, experts and analysts are more likely to generate strategies that better address these needs.

Formulating specifications: The goals and requirements of the project articulated in the first phase are necessity of a general nature. This is largely because it is rarely productive to embark upon an exercise to specify project components without a broad understanding of decision support needs. Furthermore, if team members begin to focus too much on project specifics early on in the overall process, they run the risk of not being able to adequately accommodate additional needs of end users (tourist) given that such needs usually tend to evolve over time and of already confining themselves to a certain mindset about implementation strategies.

However, once an overall understanding of project requirements has been developed among team members, it is helpful to develop a listing of more functional specifications corresponding to each of the requirements that have been identified. For instance, if the project requires that the final GIS be interactive (implying that the end user can explore alternate scenarios on their own), one or more of the following are representative of possible functional specifications, capability of generating and editing different thematic maps, features for querying attributes in spatial databases, support for adding new themes and/or updating current information in the GIS over time, enabling application of the analytical approach to different geographical regions and capability to modify existing models and/or link new models to the GIS.

The process of identifying functional specifications involves an in-depth analysis of each of the project requirements. In practice, it is usually beneficial for the

subject matter experts and GIS analysts to first formulate project specifications jointly and to then share these with the end users. This approach tends to result in time (and therefore cost) savings.

Developing the analytical framework: The two phases deal primarily with aspects of what is to be accomplished (i.e., project needs). Development of the analytical framework for a GIS project, on the other hand, addresses issues of how these needs will be addressed.

This phase largely involves subject matter specialists and GIS analysts (Fig. 1). However, consultations with end users tourist as the case may be are recommended to ensure that the project will indeed address their needs, to accommodate new needs that may arise and to foster an improved understanding of analytical methods that may be used. Several methods have been used, either singly or in combination, by GIS practitioners to integrate spatial information into a useful format for analysis and decision making. These analytical methods could have potential for use in the ecotourism development. Their inclusion here is intended to provide readers with an overview of the range of analytical methods that may come up for discussion during this phase of a GIS project.

Arithmetic operators: A large number of arithmetic operators can be used in GIS (Burrough, 1986). For instance, a useful precursor is the scalar operation in which a constant term is to be applied to spatial data (e.g., to estimate the potential weekly, monthly and annual tourist in a region).

Classification: It is almost always the case that the source data, whether in real or integer format, will need to be further classified before further use. Classification is an essential part of any data reduction process, whereby complex sets of observations are made understandable. Although any classification process involves some loss of information, a good scheme not only aims to minimize this loss, but by identifying natural groups that have common properties, provides a convenient means of information handling and transfer (Burrough, 1986). Further, in any classification process, care must be taken to preserve the appropriate level of detail needed for sensible decision making at a later stage such as income, age, educational background, cultural background of tourist (Burrough, 1986; Ross, 1998; Onosemuode *et al.*, 2008).

Simple overlay: The most common technique in geographic information processing is that of topological overlaying in which multiple data layers are overlain in a

vertical manner. Topological overlays may be broadly classified into simple and weighted methods. After reclassification of thematic maps in terms of suitability for an activity has been accomplished, simple overlay can be accomplished by applying mathematical or logical operators to the layers. This can often generate very valuable outcomes. Simple overlays operations assume that all layers have equal importance. Outcomes of the operation can be further refined if they are overlain with constraint layers by subtraction. A more common practice, however is to represent constraint layers in Boolean format, with disallowed and allowed areas defined as 0 and 1, respectively.

In this way, when the constraint layer is multiplied by one containing suitability data, the former is automatically excluded from the outcome. A series of such simple reclassifications and overlays can be assembled as a tree of sequential choices (i.e., a decision tree) to provide a rational outcome to a spatial problem. Examples of constraint layers are large water bodies and forested lands that are unavailable for ecotourism development.

Neighbourhood analysis: A key function provided by GIS and one which cannot be easily addressed by the use of any other decision support tool is its capability to allow evaluation of the characteristics of an area that surrounds a specific location, which is referred to as neighbourhood analysis. GIS software provides a range of neighbourhood functions including point interpolation techniques in which unknown values are estimated from known values of neighbouring locations. These techniques are typically used to convert point coverage into grids or to generate elevation data either in Triangular Irregular Network (TIN) format for vector GIS or as a Digital Elevation Model (DEM) for raster GIS. DEMs have not as yet found widespread use in tourism but are often at the heart of environmental GIS that are targeted towards analyses of entire landscapes. For instance, the DEM for a watershed of interest is a key layer in many spatially explicit hydrological models. In the future, such tools are likely to find applications in ecotourism development from the perspectives of assessing water availability and modelling environmental impacts of existing and/or proposed ecotourism operations.

A common type of neighbourhood operation is buffering, which allows the creation of distance buffers (or buffer zones) around selected features. An example where this operation may be useful in ecotourism is when there is a need to determine how many streams, aquatic lives, sand beaches, bays and forest are available (or to be avoided) within a specified distance of a proposed facility or infrastructure.

Connectivity analysis: This type of analysis is characterized by an accumulation of values over the area that is being traversed. Support for connectivity analysis in commercially available GIS software is not as standardized in comparison to the operators described above. Network analysis is one type of connectivity operation, which is characterized by the use of feature networks such as hydrographic hierarchies (i.e., stream networks) and transportation networks. As an example of the use of network analysis in tourism.

Multi-objective land allocation: Once an activity has been modelled and quantified, it will invariably have some potential to conflict with other uses of the space or resources. For example, practices such as agriculture, forestry, aquaculture and ecotourism may compete for available land and associated resources. This calls for trade-off decisions to be made so that activities can coexist. These decisions typically require consideration of economic, environmental and social ramifications of alternative land use practices. Decision support tools are available in some GIS packages to facilitate this process. The Multi-Objective Land Allocation (MOLA) and multi-dimensional decision space (MDCHOICE) tools in IDRISI are good examples. MOLA was used by Aguilar-Manjarrez and Ross (1995) to identify areas suitable for agriculture and aquaculture across the Sinaloa state of Mexico. Inputs for the MOLA technique originate from the results of weighted overlays. The approach allows GIS analysts to set limits on areas required for different land uses and assign requirements for these uses. An iterative process is then used to successively reassign ranked cells to alternate activities depending upon how closely they match the associated requirements.

Identifying data sources: Once the analytical framework has been developed, it is necessary to identify data sources to be used in the project. This phase is largely restricted to GIS analysts (Fig. 1), although subject matter specialists often provide helpful advice (e.g., identifying non-spatial datasets). Information for spatial decision-making and analysis is varied and will usually consist of data describing the ecological, biophysical, economic, social and infrastructural environments. These data can come from a variety of sources ranging from primary data gathered in the field or satellite scenes to all forms of secondary data, including textual databases and reports. It is generally both costly and time consuming to collect field (primary) data first hand. Therefore, all GIS practitioners attempt to locate the data they need from existing secondary

sources, either in paper or digital form. The initial consideration is identifying what data are needed for the overall analysis. This is followed by attempts to source the data and to assess their age, scale, quality and relative cost.

Organizing and manipulating data: After datasets have been collected, it is necessary to organize and manipulate them for use in the target GIS. This phase is also largely restricted to GIS analysts (Fig. 1), although depending on the type of application, occasional interaction with subject matter specialists may be warranted. Some of the key activities that occur in this phase include verification of data quality, data consolidation and reformatting, creation of proxy data and database construction. Proxy data refer to information that is derived from another data source, for which established relationships may exist.

Satellite images provide a rich source of data in a form suitable for use in a spatial database. The information collected by the scanners on LANDSAT and SPOT and other satellite imageries are aimed specifically at natural resource work and the source data can be reprocessed in a variety of ways to reveal details of the environment that may not be apparent in the raw state. Satellite images are vital tools for spatial decision support in eco-tourism development. Most GIS packages have tools to assist with reprocessing, including the ability to filter and clean up the image, make corrections for atmospheric variations and allow georeferencing of the image to known reference points (Burrough, 1986).

Database construction is another set of activities that is typically undertaken in this phase. Designing an appropriate database is important both in terms of ensuring that the information can be readily accessed for the target application and is available for re-use at a later time. It has been the case in the past that spatial data were usually stored in formats suited to the type of GIS software being used. This often resulted in spatial databases that were not relatively easy to extract either for use in other types of applications or software. However, many organizations are taking advantage of recent advances both in GIS and database technology by storing both raw and processed information in relational databases. Such data can seamlessly be imported for use in stand-alone GIS applications.

Analyzing data and verifying outcomes: This phase represents the culmination of effort that has been expended, particularly on the part of GIS analysts, to develop the analytical framework, locate data sources and organize data for the analysis. As can be expected, the GIS analysts play the most important role in this phase

but are likely to interact with subject matter specialists and end users in terms of verifying preliminary results (Fig. 1).

Activities that may be encountered in this phase include executing analytical methods (i.e., overlays, model runs and/or other querying knowledge based systems, etc.), importing and exporting data as needed (e.g., intermediate GIS outputs which are required by other components within the overall analytical framework), computation of relevant statistics (e.g., means, standard deviations, ranges, classes, etc.), generation of output information (e.g., maps, tables, graphs and reports) and verification of outcomes.

Global Positioning Systems (GPS) have greatly aided the spatial accuracy of ground-truthing and field verification, in most cases removing the need to use surveying techniques completely. These systems provide three-dimensional position locations from satellites to within about 100 m under normal operation, although actual accuracy is frequently as good as 20 m or even less. By operating in differential mode, two GPS units can give real-time locations accurate to <1 m and with post-processing to within a few millimetres (Aguilar-Manjarrez, 1996). The value of these systems has been rapidly recognized by GIS practitioners.

Some GIS data acquisition systems will accept direct input from GPS so that the location can be displayed over a real satellite image of the study area. Apart from verifying data and outcomes of models, field verification can provide feedback into the analytical process itself by allowing the GIS analysts and subject matter specialists to understand, quantify and document errors of the assumptions used. Such documentation should be an integral part of the overall project report.

Evaluating outputs: In this final phase of a GIS project, outputs generated are jointly evaluated by the overall team (i.e., end users, subject matter specialists and GIS analysts; Fig. 1). Several activities are likely to be encountered during this phase, including a summary review of key findings, more detailed examination of individual components of the project together with their underlying assumptions, limitations (if any) of the findings and an evaluation of the degree to which each of the original requirements of the project have been met. The results of the latter activity provide a useful means of assessing the success of the project. However, it is often the case that outputs from a GIS project are not put to immediate use, but form a component of a larger decision making process (e.g., development of new policies and/or development plans pertaining). In this regard, it may be difficult to properly assess the value of the information

generated by a GIS project and therefore, its contribution towards decision support. If careful attention is given to this aspect at the beginning of a GIS project (i.e., during the phase of identifying project requirements), it should be possible to develop a set of indicators which can be measured over time and used to track how GIS information is used in ecotourism decision making by end users. Feedback from such indicators is likely to be helpful in improving further GIS development and application. Clearly, there is need for typical end users, subject matter specialists and spatial analysts to collaborate more actively in the development and application of GIS for ecotourism development.

CONCLUSION

The relationship between tourism and conservation can be a symbiotic one. The benefits that a well-managed coastal area can accrue to the tourist industry are clear; however, tourism can also facilitate the protection of coastal areas. If tourism is properly controlled using GIS as spatial decision support tool, it can create the conditions necessary to support the process of conservation through productive planning and comprehensive management.

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