GIS software selection technique based on multicriteria decision making

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Building a new GIS project is a major investment. Choosing the right GIS software package is critical to the success and failure of such investment. The problem of selecting the most appropriate GIS software package for a particular GIS project is a multi criteria decision making (MCDM) problem. Solving this problem requires consideration of a comprehensive set of variables and balancing of multiple objectives in determining the suitability of particular GIS software for building certain specified and well defined application. This study investigates various software selection techniques which provide decision makers with useful insights to enhance the software selection process; also this study provides a model for GIS software selection process. The proposed model is promising to be applied for improving the decision making process.

يعد اختيار البرامج الخاصة بإنشاء نظم معلومات جغرافية من المشاكل الهامة والتي يتوقف عليها نجاح أو فشل بناء نظام المعلومات الجغرافي المستهدف وحل هذه المشكلة يتطلب الأخذ فى الاعتبار مجموعة من المتغيرات التي تأثر فى المشكلة مع الموازنة بين مجموعة الأهداف المراد تحقيقها من خلال بناء المشروع. هذه الدراسة تلقي الضوء على أهم التقنيات المستخدمة فى اختيار البرامج المناسبة التي تُزوّدُ صانعيَ القرار برؤى مفيدة لتحسين عملية اختيار البرامجَ؛ أيضاً هذه الدراسةِ تقدم نموذج لاختياربرامج نظم المعلومات الجغرافية لمشروع جغرافي معين و النموذج المقترح يحسن اتخاذ القرار فى عملية اختيارهذه البرامج.

Keywords: Software criteria, Software selection techniques, Multiple criteria in software selection, Software selection process

1. Introduction

Geographic Information Systems (GIS), a promising branch of Information Systems (IS), have achieved considerable success in recent years. This area of IS has concentrated on the construction of computer-based information systems to support capturing, management, manipulation, analyzing, modeling and displaying of spatially referenced data for solving complex planning and management problems. GIS software is the processing engine and a vital component of an operational GIS. It is made up of integrated collections of computer programs that support capturing, storage, processing, analyzing, management, updating, querying, and displaying of geographically referenced data Longley et al. [1]. In the last few years, the GIS software market has undergone remarkable changes. The number of GIS software packages/tools has increased significantly and prices have declined dramatically. Many of these packages/tools were developed to fit different user needs and were designed to execute on a variety of hardware platforms Longley et al. [1]. Building a new GIS project is a major investment. Choosing the right GIS software package/tool is critical to the success and failure of such investment, i.e., the impact of a bad decision can be high not only in monetary terms but in terms of its impact on management's attitude Eldrandaly [2]. The problem of selecting the most appropriate GIS software package/tool for a particular GIS project is not a well defined or a structured decision problem. The presence of multiple criteria and the involvement of multiple decision makers will expand decisions from one to several dimensions; this will lead to the

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complexity of solution process. An inappropriate selection strategy of GIS software can lead to adverse effects, it could result in a short list of GIS packages that may not be able to fulfill the required functionality; in addition, it might introduce overhead costs in the system integration and maintenance phases. Solving this problem requires consideration of a comprehensive set of variables and balancing of multiple objectives in determining the suitability of particular GIS software for building certain specified and well defined application. This paper discusses the most essential criteria used in software selection and investigates different software selection techniques; also it provides a model for selecting GIS software in which Expert Systems and MCDM technique (AHP) are integrated together to aid in solving the problem of GIS software selection.

2. Software selection criteria

In order to choose the suitable software that fulfills user/organization needs, it is necessary to determine the criteria upon which the software will be evaluated. To address this knowledge, a review literature for software selection and evaluation has been done and studying the international standard ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) ISO/IEC 9126 which provides a framework for the evaluation of software quality. There are fourteen criteria could be used for selecting any package software, these criteria are: maintainability, dependability, efficiency, usability, cost, vendor support, portability, ease of use, reliability, ease of customization, ease of implementation, performance, compatibility, and functionality.

2.1. Maintainability

Software should be written in such a way that it may evolve to meet the changing needs of customers. This is a critical criterion because software change is an inevitable consequence of a changing business environment Sommerville [3]. Also, ISO/IEC 9126 [4] defines four subcriteria of Maintainability; these subcriteria are analyzability, changeability, stability and testability.

2.2. Dependability

The dependability of a computer system is a property of the system that equates to its trustworthiness. Trustworthiness essentially means the degree of user confidence that the system will operate as they expect and that the system will not fail in normal use. Summerville [3] defines three sub criteria for dependability. These subcriteria are availability, safety, and security.

2.3. Efficiency

Software should no make wasteful use of system resources such as memory and processor cycles. Efficiency therefore includes responsiveness, processing time, memory utilization, etc Sommerville [3]. Also, [4] defines two subcriteria of Efficiency. These subcriteria are time behavior and resource behavior.

2.4. Usability

Usability is the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments Tiits [5]. ISO/IEC 9126 [4] defines three subcriteria of usability. These sub criteria are understandability, learnability, and operability.

2.5. Cost

Cost is an important factor in selecting software packages. It is simply the expenditure associated with the software and includes product, license, training, maintenance, and implementation of the package, software subscription and support services costs. Technically, these costs can be grouped under two major criteria, namely, capital expenditures and operating expenditures. Capital expenditures are the non-recurring costs involved in setting up the software. They include product costs, license costs and training costs. Operating expenditures are the recurring costs involved in operating the

software, which include maintenance costs and software subscription costs, costs of support services, and data customization or conversion costs (Lai et. al [6]; Hulpic and Paul [7]; Tam and Tummala [8]; Technology Group International, [9] Sarkis and Talluri, [10]; Adhikari et. al, [11]; Nagi and Chan, [12]).

2.6. Vendor support

The quality of vendor support and its characteristics are of major importance in the selection of software. Technically, vendor specific criteria include quality of support services, costs of support services, delivery lead time, vendor's experience in related products; vendor's experience in the application area, vendor's training capabilities, problem solving capabilities, qualification of staff, continuous enhancement, stability of vendors and vendor's reputation Lai et al. [6]; Tam and Tummala [8]; Technology Group International [9]; Adhikari et al. [11] Nagi and Chan [12] ; Keil and Tiwana [13].

2.7. Portability

Portability is primarily related to the degree of modularity. Modularity is technically defined as the ability to independently install and use separate sets of a package's functionalities referred to as modules, which is fundamental to integrate packages into a company's information system by parametrizing their interfaces and avoiding cumbersome software redesign activities. ISO/IEC 9126 [4] defines four subcriteria of portability. These subcriteria are adaptability, installability, conformance, and replaceability.

2.8. Ease of use

This refers to the intuitiveness of the software and the package that should be easy and straightforward to use [13]. This include:

- The user interface is easy to navigate and uncomplicated.
- The interface presents results in a meaningful way.
- Easy access to the help files.
- Existence of relevant help and error messages.
- The tool is easy to learn and easy to use correctly.

2.9. Reliability

Software Reliability is an important attribute of software quality. It is necessary that the reliability of software should be measured and evaluated, as it is in hardware. The process of optimizing the reliability of software through a program that emphasizes software error prevention, fault detection and removal, and the use of measurements to maximize reliability in light of project constraints such as resources, schedule and performance Keil and Tiwana [13]. ISO/IEC 9126 [4] defines three subcriteria of reliability. These subcriteria are maturity, fault tolerance, and recoverability.

2.10. Ease of customization

Customization refers to the extent to which this package can be easily modified and adopted to meet the organization's need (Keil and Tiwana [13]; Hulpic and Paul [7].

2.11. Ease of implementation

It refers to the setup time and effort that will be required to implement the package in the organization [13].

2.12. Performance

The capability of the technology for delivering the expected results in different processing environment Mulebeke and Zheng [14].

Performance criteria as mentioned in Collier et al. [15]:

- Software should run on a wide variety of computer platform.
- The user should have a choice of architecture to use such as client server or stand alone architecture.
- The software should interface with other support tools easily.

- Software should produce results in a reasonable amount of time relative to the data size.
- Software should run consistently without crashing.

2.13. Compatibility

It refers to how well the software works with existing software and other packages easily Hulpic and Paul [7]; Lai et al. [6]; Tam and Tummala [8]; ABC Computers .Inc [16].

2.14. Functionality

Functionality refers to extent to which the software package contains all the features and functions specified in your Request For Proposal (RFP) which is generated based on the organization needs assessment (Keil and Taiwan [13]. ISO/IEC 9126 [4] defines five subcriteria of functionality. These subcriteria are suitability, accurateness, interoperability, compliance, and security. According to measureing the importance of each criterion, table 1 shows how the articles were reviewed and mapped against each of these criteria with the frequency of occurrence for each criterion.

3. Software selection techniques

Many techniques are used in the area of software selection. Those techniques are: ranking and scoring methods, goal programming, fuzzy logic, Analytic Hierarchy Process (AHP), and Analytic Network Process (ANP).

3.1. Ranking and scoring methods

Ranking and scoring are traditional approaches for software selection. In ranking approach, the available software solutions are ranked based on their relative contributions to a given criteria. The process is repeated for every criterion. The ranks are aggregated and used for decision. The scoring approach is similar, except that available software solutions are scored on a scale rather than being ranked. The aggregated sores or rank are used in selection decision Collier et al. [15] Bandor [17].

3.2. Goal programming

Sarkis and Talluri [10] presented a decision framework that could aid members of the supply chain and a supply chain director in deciding which electronic commerce technology media and software is most suitable for the whole supply chain. This framework is based on both the analytical hierarchy process and goal programming. Kwak et al. [18] used goal programming to select an advertising media for the digital appliance products of a manufacturing firm. The basic idea of the technique is to convert the multiobjective problem into one or more problems with one objective for each.

3.3. Fuzzy logic

Machacha and Bhattacharya [19] developed a system for database software selection using fuzzy logic. Lin et al. [20] used the fuzzy logic for optimal selection of data warehouse system systems. The power of fuzzy logic comes from the ability to describe particular phenomena or process linguistically and to represent that description in a small number of flexible rules.

3.4. The analytic hierarchy process

Analytic Hierarchal Process (AHP) is a multicriteria decision making technique that allows the consideration of both tangible and intangible factors in selecting the best alternative. This approach is used to arrive at a ratio-scale cardinal ranking of alternatives for multiattribute decision problems. AHP has been used widely in software selection. Lai et al. [6] discussed the applicability of AHP in problem solving and how it can be applied to the selection of multimedia authorizing system. Ossadnik and Lange [21] evaluated the quality of three software products supporting the AHP using AHP decision model. [22] applied AHP to evaluate and select antivirus and content

filtering software. Colombo and Francalanci [27] provide a study that describes a hierarchical ranking model to help the selection of Customer Relationship Management (CRM) packages based on their functional and technical quality. The model is tested empirically by applying AHP to a sample of 42 CRM packages. Eldrandaly [12] applied AHP model to a hypothetical case study to examine its flexibility in solving GIS software selection problem. The use of the proposed model indicates that it can be applied to improve the decision making process and to reduce the time taken to select a GIS software.

3.5. Analytic network process

The Analytic Network Process (ANP) differs from AHP in that it generalizes the pairwise comparison process so that decision models can be built as complex networks of decision objectives, criteria, stakeholders, alternatives, scenarios, and other environmental factors that all influence one another's priorities. The key concept of ANP is that influence does not necessarily have to flow only downwards as in case of AHP. Influence can flow between any factors in the network causing non-linear results of priorities of alternative choices. Mulebeke and Zheng [14] ANP to help in the selection of appropriate software to suit the product development process of a particular product. Table 2 lists the advantages and disadvantages of the presented software selection techniques Bandor [16]; Collier et al. [15]; Eldrandaly [2]; Kontio [23]; Kwak et al. [18] Lai et al. [6]; Machacha and Bhattacharya, [19]; Sarkis and Talluri [10]; Mulebeke and Zheng [14]; Lin et al. [20].

Table 2
Advantages and disadvantages of software selection techniques

Technique	Advantages	Disadvantages
Ranking and scoring methods	1-It is allows decisions to be based on several criteria 2-It is capable of handling tangible and intangible criteria 3- It is transparent, allowing others to see the logic of the results 4-It is cheap and simple, and therefore allows participation of non specialists.	1-It fails to provide the decision maker with a means to evaluate the relative importance of the criteria. 2-It aggregates aggregation of ranks or scores in an attempt to convert the multi-dimensional problem into a single dimensional problem, however such aggregation completely ignores the varying levels of importance placed upon each criterion.
Goal programming	1-It can be used in any decision scenario in which the decision maker is capable of (i) Assigning quantitative values to the alternatives on the basis of the criteria and (ii) Assigning a minimal performance level to each criterion under consideration.	1-It requires high level of skills. 2-It may result in an intensive data in the complex problem due to the large number of constraints. 3-It seeks an efficient solution not an optimum one due to the conflicting objectives. 4-It provides no ranking to the relative importance of the goal.
Fuzzy logic	1-It ca quantify imprecise or imperfect information 2-It cab make decisions based on vague and incomplete data programming capability.	1-It needs experts for rule discovery (data relationships). 2- It is difficult to estimate membership function 3-There are many ways of interpreting fuzzy rules, combining the outputs of several fuzzy rules and defuzzifying the output.
AHP	1-The methodology of the AHP is similar to that used in common sense decision making 2-It is easy for most decision makers to understand, integrates subjective judgments with numerical data. 3-It allows the Quantification of intangible through the construction of the problem in a visual hierarchal manner. The hierarchy serves to create priority structures relevant to specific decision problem, 4-Several commercial software packages are available to assist in conducting AHP analysis, such as Expert choice.	1-The length of the process, which increases with the number of levels and number of pair wise decisions. 2-It could not include interrelationship and feedback within the elements in the model.

ANP	It has same advantages of AHP in addition to dealing with the interdependency among clusters	It becomes more difficult with complex problem.

4. GIS software

GIS software packages/tools provide a unified approach to working with geographic information. GIS software vendors, the companies that design, develop and sell GIS software, build on the top of basic computer operating capabilities. The latter include security, file management, peripheral drivers, printing and display management. GIS software is constructed on these foundations to provide a controlled environment for geographic information collection, management, analysis, and interpretation. GIS software is a fundamental and critical part of any operational GIS. The GIS employed in a GIS project has a controlling impact on the type of studies that can be undertaken and the results that can be obtained. There are also far reaching implications for user productivity and project costs. Today, there are many types of GIS software product to choose from and a number of ways to configure implementations [1]. Longley et al. classified GIS software into the five main types. These types are desktop GIS software, server GIS, developer GIS, handheld GIS, and other types of GIS software. Desktop GIS software owes its origins to the personal computer and the Microsoft Windows operating system and is considered the mainstream workhorse of GIS today. It provides personal productivity tools for a wide variety of users across a broad cross section of industries (Longley et. al. [1]). The desktop GIS software category includes a range of options from simple viewers (such as ESRI ArcReader, Intergraph GeoMedia Viewer and MapInfo ProViewer) to desktop mapping and GIS software systems (such as Autodesk Map 3D, ESRI ArcView, Intergraph GeoMedia, and MapInfo Professional), and at the high-end, full-featured professional editor/analysis systems (such as ESRI ArcGIS ArcInfo, Intergraph GeoMedia Professional, and GE Smallworld GIS). Server GIS runs on a computer server that can handle concurrent processing requests from a range of networked clients. Initially, it focused on display and query applications, but now offers mapping, routing, data publishing, and suitability mapping. Third generation server GIS offers complete GIS functionality in a multi user server environment. Examples of server GIS include AutoDesk MapGuide, ESRI ArcGIS Server, GE Spatial Application Server, Intergraph GeoMedia Webmap, and MapInfo MapXtreme. Developer GIS software are toolkits of GIS functions (components) that a reasonably knowledgeable programmer can use to build a specific-purpose GIS application. They are of interest to developers because such components can be used to create highly customized and optimized applications that can either stand alone or can be embedded with other software systems. Examples of component GIS products include Blue Marble Geographics GeoObjects, ESRI ArcGIS Engine, and MapInfo MapX. Most of the developer GIS products from mainstream vendors are built on top of Microsoft's COM and .Net technology standards, but there are several cross platform choices (e.g., ESRI ArcGIS Engine) and several Java-based toolkits (e.g., ObjectFX Spatial FX). Hand-held GIS are lightweight systems designed for mobile and field use. A very recent development is the availability of hand-held software on high-end so-called 'smart phones' which can deal with comparatively large amounts of data and sophisticated applications. These systems usually operate in a mixed connected/disconnected environment and so can make active use of data and software applications held on the server and accessed over a wireless telephone network. Examples of Hand-held GIS include Autodesk OmSite, ESRI ArcPad, and Intergraph Intelliware. Other types of GIS Software include commercial and non-commercial software that provide valuable GIS capabilities such as public-domain, open source and free software. For example, Geographic Resources Analysis Support System, commonly referred to as GRASS GIS, is a Geographic Information System (GIS) used for data management, image processing, graphics production, spatial modeling, and visualization of many types of data. It is a Free (Libre) Software/Open Source released under a GNU General Public License (GPL).

5. GIS software selection criteria

In order to formulate the decision model, it is necessary to identify the factors that influence the choice of GIS software. After, reviewing the literature for software evaluation and selection (ABC Computers Inc, [16]; Brown and Stephenson, [24]; Chau [26]; Goldenberg [29]; Johannsen [31]; Keil and Tiwana [13]; Maiden and Ncube; Technology Group International [9]) and studying the international standard ISO/IEC 9126. Five essential evaluation criteria to use in selecting the best GIS software are identified. These criteria are cost, usability, reliability, vendor support, and functionality.

Cost, usability, reliability and vendor support were discussed earlier. The functionality criteria are major key elements in the GIS software selection.

Based on a review of the literature (Longley et al. [1]; Point of beginning [40]; Tiits [5]) eleven key functional elements of a GIS tool are identified. These functional elements are presented below.

5.1. Operating system/network support

This is always the first important consideration. Verify your OS supports the product best suited to your particular needs. If you want to operate on a network, be sure the OS is robust enough and the GIS software supports network licensing, such as Network Client-Server Support, Server Operating System, Client Operating System, and Internet Server Enabled.

5.2. Geographic data management

These are database administration tools for managing data access by users, locking of data during edit and maintenance of metadata.

5.3. Tabular attribute data management

Software environment and capabilities for storing and managing database attributes linked to map features in the GIS database May involve use of a vendor-proprietary system for attribute storage or a commercial relational database management package.

5.4. GIS data import/export utilities

These are utility programs bundled with the GIS package for translation of GIS or CAD data to or from another format, including common industry-standard formats like DXF, SIF, DLG or SDTS.

5.5. GIS data entry and editing

It is a range of interactive and batch processing functions for entry of map data through such means as board digitizing, coordinate geometry entry (COGO), scanning and heads-up digitizing, along with capabilities for editing GIS data, performing error checking and resolution, map rectification and transformation of coordinate systems and map projections.

5.6. Map design and composition

They are interactive capabilities for the design of map plots and displays, automatic creation of thematic maps and legends, and modifying map symbology and annotation for custom map displays.

5.7. Basic geographic query and analysis functions

They are the basic tools for performing attribute or map-based queries and displays, basic distance and area measurements, query and access to scanned documents, buffer generation, polygon overlay operations and other query and analysis functions.

5.8. Network analysis

These spatial analysis operations are based on linear networks (e.g., road or pipeline systems), including such operations as shortest path tracing and region allocation. Network analysis capabilities in GIS packages often allow users to design network models based on attributes of network segment.

5.9. Terrain and 3-D data processing and analysis

They are the capabilities for storing three-dimensional data normally in a grid or Triangular Integrated Network (TIN) format with functions for 3-D analysis such as contour mapping, 3-D display, draping of map features over a 3-D display, slope and aspect analysis, etc.

5.10. Raster image processing capabilities

They are the capabilities for the manipulation and processing of raster images (e.g., digital aerial photos or orthophotography, satellite images), including functions for the import and rectification of raw imagery, digital image enhancement and automated classification of multi-spectral imagery.

5.11. Application development languages

It is programming environment for customizing applications accessing software functions provided by the package, including proprietary languages included with the GIS software package or industry standard tools (e.g., C++, Visual Basic, Delphi) that may be used for application development.

6. The proposed model for GIS software selection

The problem of selecting the most appropriate GIS software for a particular GIS project is a Multi Criteria Decision Making (MCDM) problem. The presence of multiple criteria (both managerial and technical) and the involvement of multiple decision makers will expand decisions from one to many several dimensions, thus increasing the complexity of the solution process. There is a harm need to build a framework to support GIS software selection process of identifying and prioritizing relevant criteria and evaluating the trade-offs between technical, economic and performance criteria. The proposed model will develop an intelligent decision support system by integrating Expert Systems (ES) and MCDM technique to build a framework to support the selection of GIS software. This model will improve not only the decision making process but also reduce the time taken to select a GIS software. The proposed system model proceeds through three phases: the justification phase, the screening phase, and the evaluation phase as shown in fig. 1.

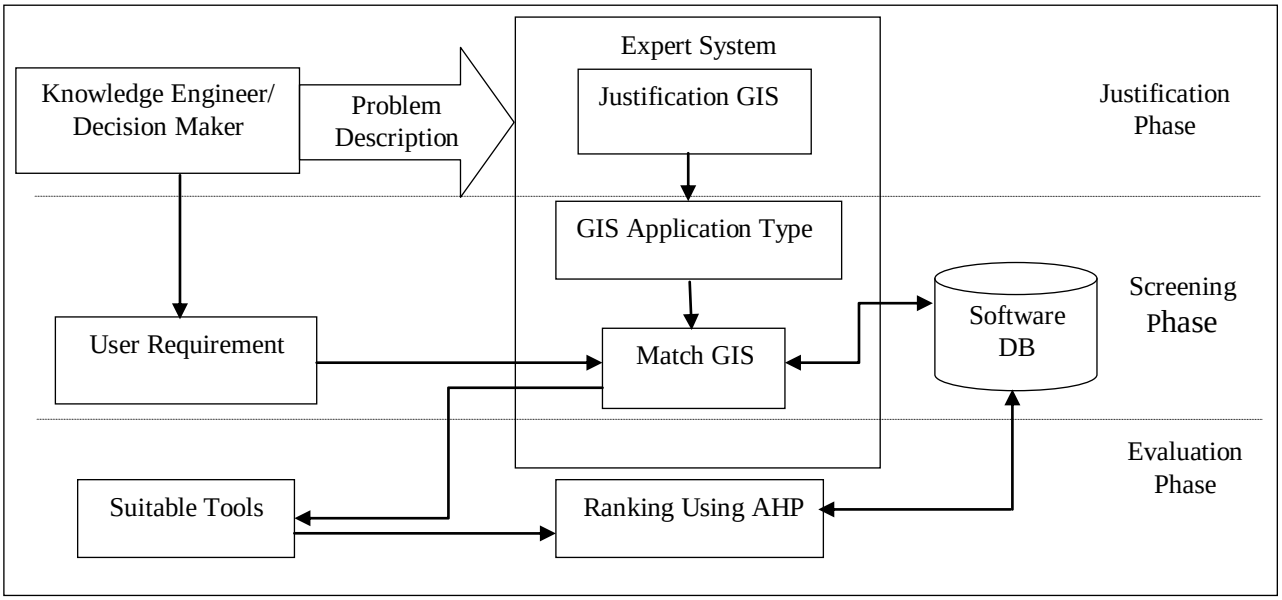

Fig. 1. System architecture.

Fig. 2 gives the high level flowchart of the search process. As shown the system initially starts with the justification phase, to justify the need for GIS software, the expert system starts to ask the user to mark at least one justification parameter from parameters exhibited in fig. 3. If no justification is determined, the program is stopped as presented in fig. 2. If GIS can solve the problem then the expert system moves to the screening phase, the expert system will ask the user about the type and the domain of the application and the user will mark the sentence that satisfy his needs as shown in fig. 4, 5. Based on the type and the domain of application the expert system will suggest the technical criteria needed in that application and enable the user to edit those technical criteria as shown in fig. 6, the expert system will match those technical criteria with the GIS software that exist in the database to identify the suitable GIS software as shown in fig. 7. Finally, the evaluation phase, the expert system ask the user to select the desired non technical criteria (such as cost, vendor support…etc) from the list as shown in fig. 8, then the user choose the degree of importance for each criteria from the list as shown in fig. 9, The expert system evaluates the suitable GIS software and identify the best one that fulfills user/organization needs using AHP technique as shown in fig. 10.

Fig. 3 to fig. 10 exhibit the interactive interface windows for the different phases of the proposed model.

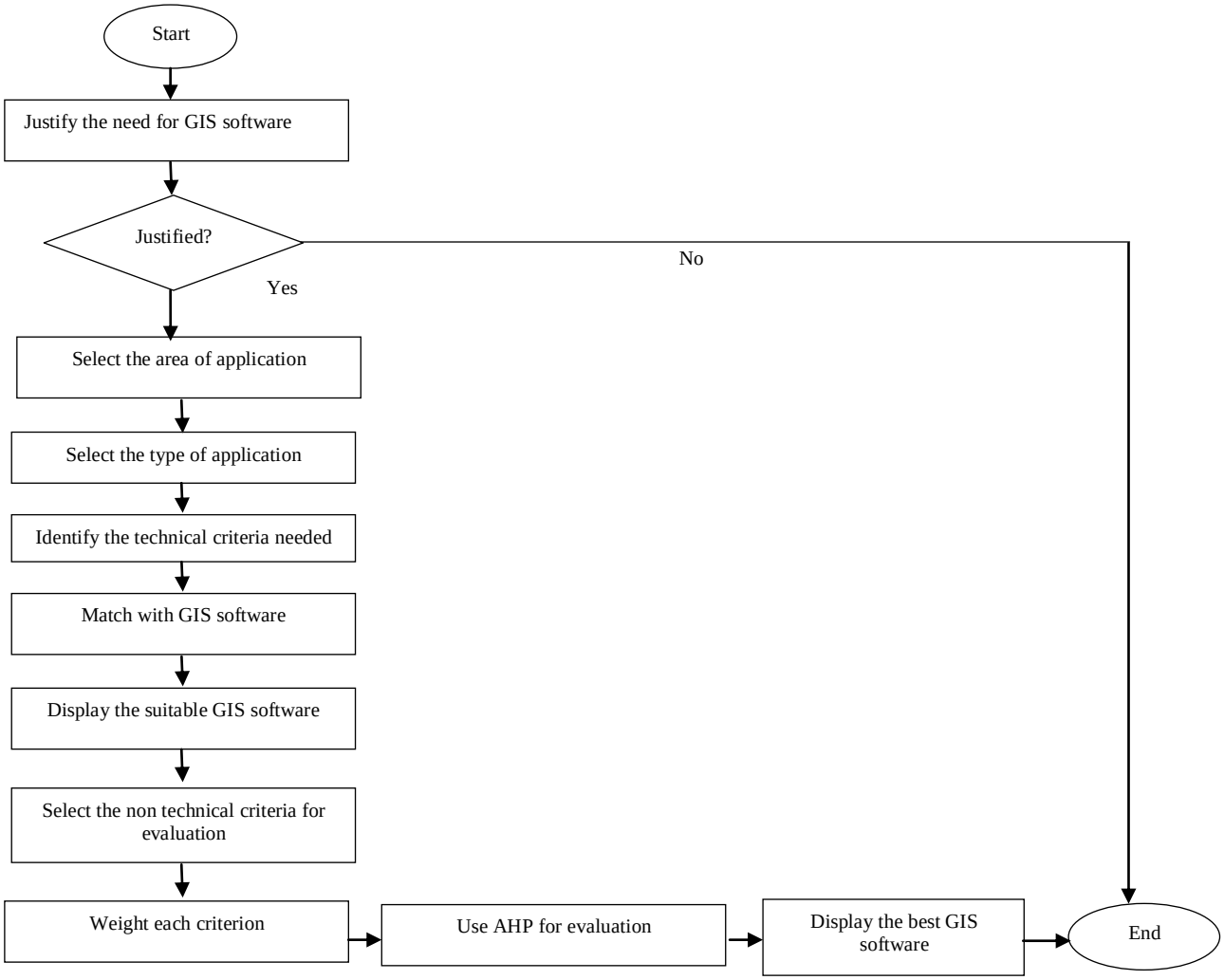

Fig. 2 overall search methodology.

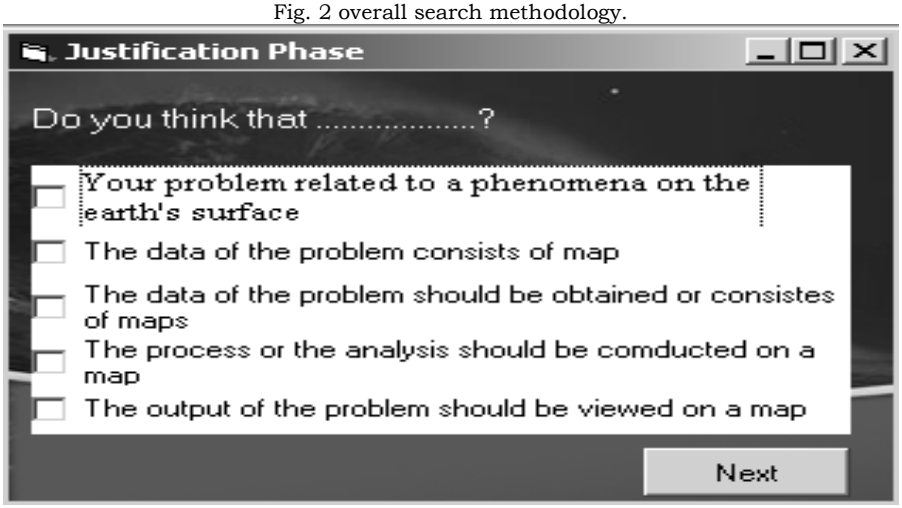

Fig. 3. Justification phase.

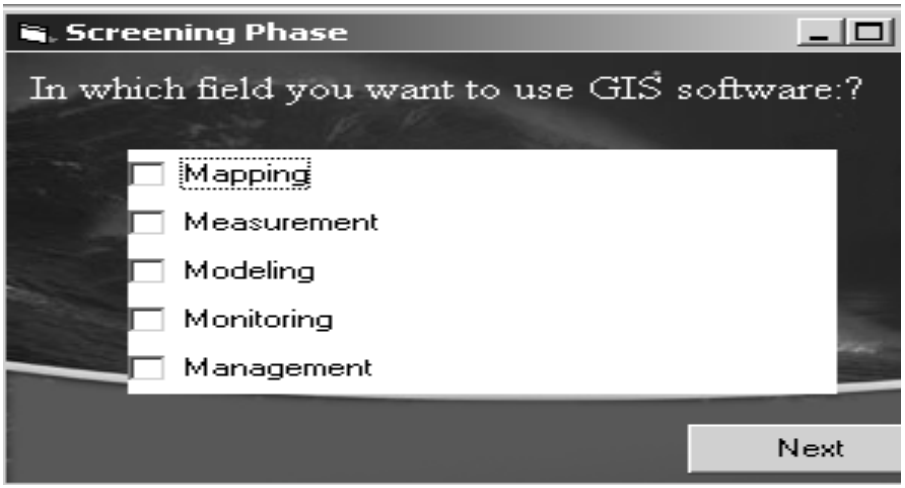

Fig. 4. Choose the area of application (screening phase).

Fig. 5. Choose the type of application (screening phase).

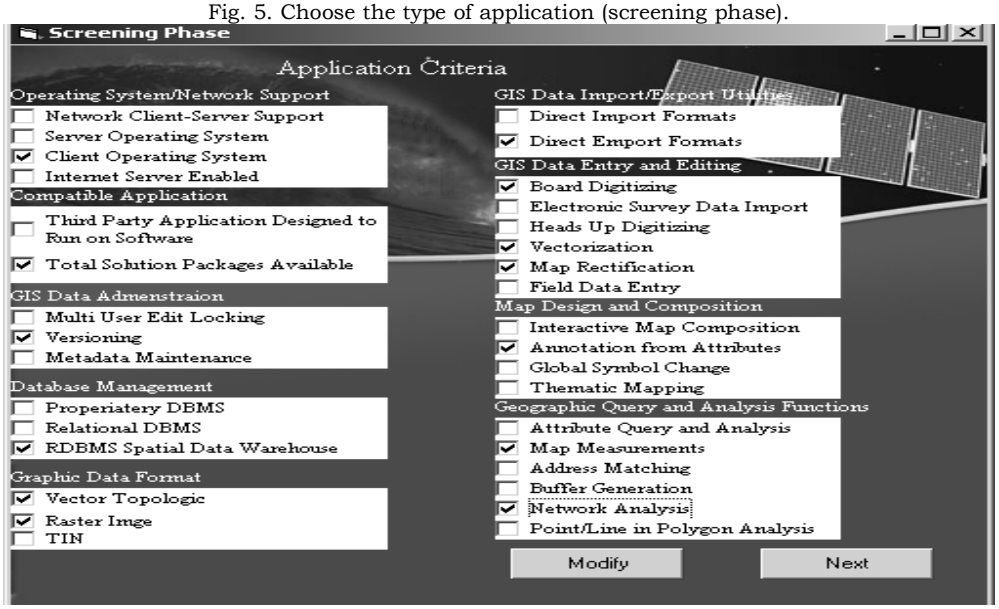

Fig. 6. Application criteria (screening phase).

Fig. 7. Suitable GIS software (screening phase).

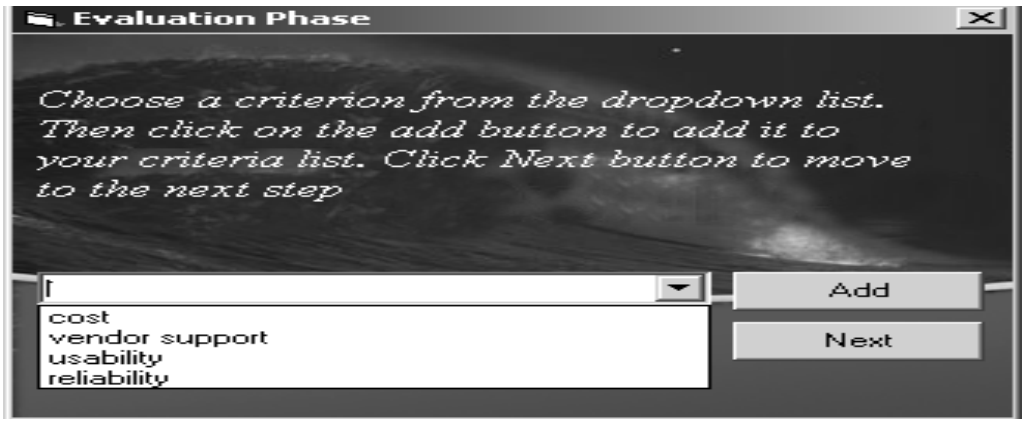

Fig. 8. Non technical criteria used for evaluation and ranking (evaluation phase).

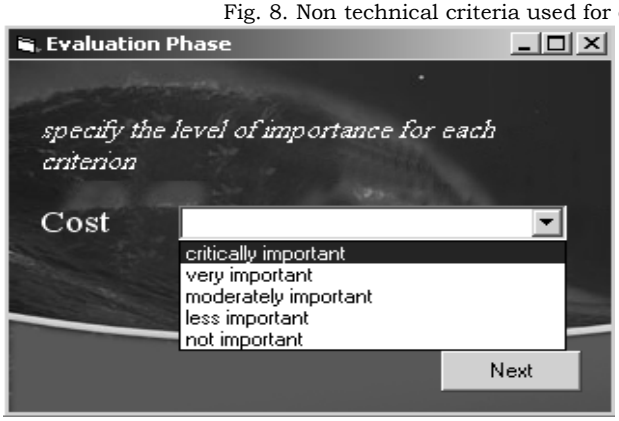

Fig. 9. Evaluation of each criterion (evaluation phase).

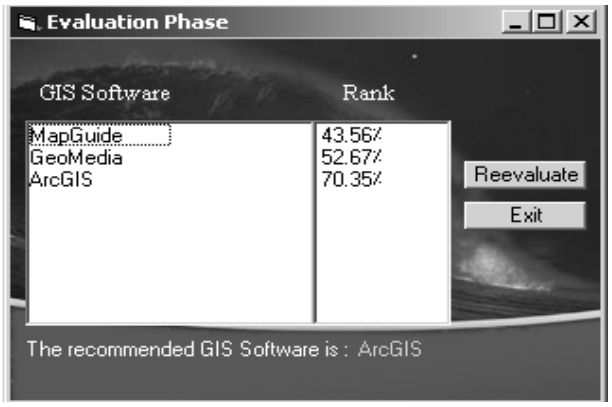

Fig. 10. Best GIS software (evaluation phase).

7. Conclusions

The paper presents the most essential criteria used in software selection and investigates different software selection techniques. This study provides a model in which Expert Systems and MCDM technique (AHP) are integrated together to aid in solving the problem of software selection.This model is being tested from GIS software specialists. The findings of this study provide decision makers with useful insights to enhance the selection process, improve decision making, and reduce the time and effort during the GIS software selection justification and selection procedure

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