

# An Expert GIS-Based ANP-OWA Decision Making Framework for Tourism Development Site Selection

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**Abstract**—The selection of a tourism development site involves a complex array of decision criteria that may have interdependence relationships within and between them. In the process of finding the optimum location that meet desired conditions, the analyst is challenged by the tedious manipulation of spatial data and the management of multiple decision-making criteria. This paper presents a novel decision making framework in which expert systems (ES), and geographic information systems–based multicriteria evaluation techniques (Analytical Network Process and fuzzy quantifiers-guided ordered weighted averaging operators (GIS-based ANP-OWA)) are integrated systematically to facilitate the selection of suitable sites for building new tourism facilities. First, ES is used for recommending the proper site selection criteria and their interdependence relationships. Then, the GIS-based ANP-OWA is used to perform the spatial data analysis necessary to generate a wide range of possible candidate sites' scenarios taking into accounts both the interdependence relationships between sitting criteria and the level of risk the decision-makers wish to assume in their multicriteria evaluation. A typical case study is presented to demonstrate the application of the proposed decision making framework.

**Index Terms**—Tourism Development Site Selection, GIS, Expert Systems, ANP-OWA, COM

## I. INTRODUCTION

Today, Tourism is considered one of the world's largest industries that supporting more than 258 million jobs worldwide and generating some 9.1% of global Gross Domestic Product (GDP) [1]. Evaluating and selecting a suitable tourism development site has become one of the most critical issues for the tourism industry. Location decision has drawn increasing attention from academic and business communities in the past two decades. It has been well recognized that selection of a facility location has important strategic implications because a location decision will normally involve a long-term commitment of resources [2].

Sitting problems are multi-faceted challenges. Not only they often involve numerous technical requirements, but may also contain economical, social, environmental and political dimensions that may have conflicting values.

Solutions for these problems involve highly complex spatial data analysis processes and frequently require advanced means to address physical suitability conditions while considering the multiple socio-economic variables. Geographic information systems (GIS), multicriteria evaluation (MCE) techniques, and Expert Systems (ES) are the most common tools employed to solve site selection problems. However, each suffers from serious shortcomings. GIS is a great tool for handling physical suitability analysis. However, it has limited capabilities of incorporating the decision maker's preferences into the problem solving process. MCE is the proper tool for analyzing decision problems and evaluating alternatives based on a decision maker's values and preferences. However, it lacks the capability of handling spatial data (e.g., buffering and overlay) that are crucial to spatial analysis. Also ES, which is capable of addressing heuristic analysis, lacks the capability of handling spatial data/knowledge. Thorough discussion of these techniques and their limitations can be found elsewhere [3]. The need for combining the strengths of these techniques has prompted researchers to seek integration of GIS, MCE and ES. Successful integration is dependent on creating a flexible and scalable framework that can provide both complex analysis tools for advanced users and disseminate information to a wide audience in a clearly understood format. The recent advances in software engineering, such as component object model (COM) technology, are now being utilized to achieve the required scalable framework and software interoperability. There is now a well-established body of literature on integrating ES, GIS and MCE techniques for solving several site selection problems (see for example: [4 – 11]). However, despite the importance of tourism development site selection decisions, there is little published research on this topic. Most of the published research on this specific topic either used the Analytical Hierarchy Process (AHP) or GIS-based AHP for choosing suitable sites for a specific tourism facility (see for example: [2, 12 – 15]). In addition, these papers did not consider the influences and interactions among the elements of the system (criteria and alternatives) as perceived by the decision

maker due to the fact that AHP cannot accommodate the variety of interactions, dependencies and feedback between higher and lower level elements [16]. Also, the GIS-based AHP, an adoption of weighted linear aggregation (WLC) rule, typically employed a high trade-off decision strategy and neglected other decision strategies [17].

This paper presents a novel decision making framework in which ES, and GIS-based ANP-OWA, a recently developed GIS-based multicriteria evaluation procedure [18], are integrated systematically to facilitate decision-making regarding site selections for tourism facilities. According to the type of the proposed tourism facility, an expert system is used to define the recommended sitting criteria (market-related, environmental, legal/political, financial etc.) and the interdependence relationships within and between them. Then, the GIS-based ANP-OWA is used to perform the spatial data analysis necessary to generate a wide range of possible candidate sites' scenarios taking into accounts both the interdependence relationships between sitting criteria and the level of risk the decision-makers wish to assume in their multicriteria evaluation. The rest of this paper is organized as follows: Section 2 presents a comprehensive discussion of tourism site selection process, and characteristics. Section 3 describes the proposed decision making framework. Section 4 describes the proposed spatial decision support system. A typical case study is presented in Section 5 to demonstrate the application of the proposed decision making framework.

II. TOURISM SITE SELECTION

2.1. Tourism Site Selection Characteristics

Building a new capital improvement facility is a major, long-term investment for owners and investors. Site selection of a capital project is a critical decision made by owners/investors that significantly affects their profit and loss. Decisions regarding the locations of these facilities influence where people work, live, and determine the life-style of a community. As such, tourism site location analysis is big business, whether measured in terms of amounts invested, decision-makers involved, employees affected, or the economies of the area influenced. The process of selection could involve a large number of candidate sites [3].

The goal in a site selection exercise is to find the best location with desired conditions that satisfy predetermined selection criteria [19]. The selection process attempts to optimize a number of objectives in determining the suitability of a particular site for a defined facility. Such optimization often involves a multitude of factors, sometimes contradicting. Some of the important factors that add to the difficulty of the proper site selection include the existence of numerous possible sites within a sought region, multiple objectives, intangible objectives, diversity of interest groups, lack of quantitative measures of the factors' impact, uncertainties

regarding impact timing and magnitude, uncertainties regarding government influence on the selection process through legislations, uncertainties regarding possible delays of permitting and construction [20].

The process for selecting tourism sites is especially complicated because there are two distinctive characteristics of tourism that add to a decision's complexity [13]: First, tourism activities frequently involve interaction with areas that are environmentally, socially, and /or culturally sensitive such as beaches, mountains, or habitats of indigenous people. The balancing of multiple objectives, e.g., maximizing a destination's popularity/attractiveness while at the same time maintaining the quality of its environment, is a formidable challenge in tourism site selection decisions. Second, in many contexts tourism is a seasonal activity because the quality of attractions, which draws people to a specific area, often varies across the year. Consequently, the popularity of areas fluctuates from season to season. This seasonality is one of the most pervasive problems in tourism leading to a highly skewed visitor distribution pattern which has substantial effects not only on a destination's profitability but also on its environment. Therefore, an inappropriate location decision may have a destructive effect not only on the success of a tourism business, but also on the host environment and community.

2.2. Tourism Site Selection Criteria

The key to success in site selection is to determine which criteria are most important. Given the multi-faceted nature of tourism and the complex nature of tourism demand, many different criteria have been identified that may influence tourism site selection. The importance of each of these criteria varies among situations depending on the type of tourism developed, the context and stage of development, and the perspective adopted. These criteria can be divided into four broad categories as shown in table 1. Thorough discussion of these criteria can be found elsewhere [13].

Table 1. Tourism site selection criteria (adapted from [13])

Categories	Criteria
Market-related Criteria	Accessibility
	Cultural Attractions
	View
	Climate
	Supporting Facilities
	Recreation Opportunities
	Competition
	Distance from Sight Line
Environmental Criteria	Topography (Slope)
	Ecosystem (Wildlife/Vegetation)
	Underground Water
	Landscape (Visual Quality)
Legal/Political Criteria	Land Use
	Surrounding Land Use
	Zoning
	Residents' Attitude
Financial Criteria	Land Price
	Existing Infrastructure
	Land Ownership
	Incentives

### III. PROPOSED DECISION MAKING FRAMEWORK

A novel decision making framework for tourism development site selection is proposed. The proposed framework integrates the capabilities of ES, and GIS-based ANP-OWA. Recommendations regarding the design of a good sitting methodology were observed [21, 22] in the design of the proposed framework. These recommendations include: a) identification of facility's goals, b) providing quality analysis (i.e., logically sound, defensible, and useful for decision-making) c) offering practical methodology (i.e., ability to conduct studies in the real environment with available methods and procedures provided at a reasonable cost and time), and d) documenting how local conditions are analyzed. Fig. 1 depicts the three phases of the proposed framework (i.e., defining sitting criteria, preparing standardized criterion maps, multicriteria evaluation) and their procedural steps as explained below:

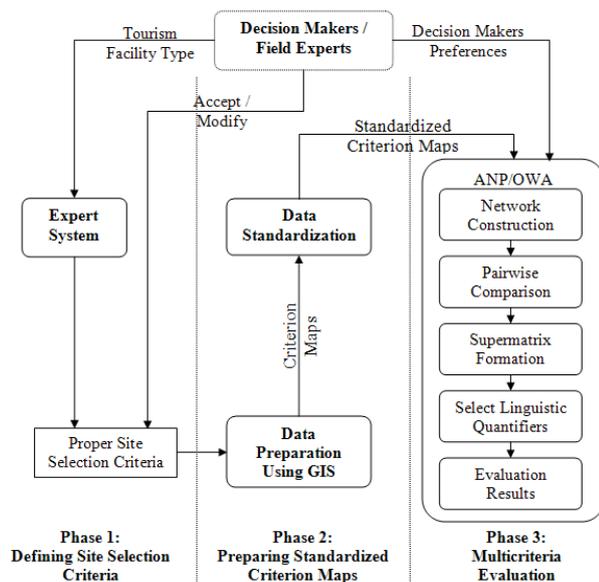


Fig. 1. Proposed Decision Making Framework

#### 3.1. Phase 1: Defining Sitting Criteria

According to the type of the proposed tourism facility, an expert system is used to define the recommended sitting criteria (market-related, environmental, legal/political, and financial etc.) and their interdependence relationships. The decision maker has the option of accepting or modifying these recommended criteria.

#### 3.2. Phase 2: Preparing Standardized Criterion Maps

After defining the sitting criteria, the analyst prepares the criterion maps based on the predefined sitting criteria. Central to spatial multicriteria decision making is the fact that an attribute can be represented in a GIS database as an attribute (criterion) map layer. A criterion map represents the spatial distribution of an attribute that measures the degree to which its associated objective is achieved. Given a variety of scales on which each

criterion can be measured, multicriteria evaluation requires that values contained in the various criterion map layers be transformed to comparable units (standardized to a common scale). Detailed descriptions of standardization approaches are reported elsewhere [23 – 25].

#### 3.3. Phase 3: Multicriteria Evaluation

After preparing the standardized criterion maps, GIS-based ANP-OWA, a recently developed GIS-based MCE procedure, is used for ranking the alternative sites according to the decision maker's preferences. ANP and OWA are two of the most commonly used GIS-based MCE procedures [26, 27]. The ANP generalizes the problem of modeling process using a network of criteria and alternatives (all called elements), grouped into clusters. All the elements in the network can be related in any possible way, i.e. a network can incorporate feedback and interdependence relationships within and between clusters. The ANP method allows the aggregation of the experts' judgments on each of these elements into one priority index [28]. However, ANP similar to AHP typically employed a high trade-off decision strategy, which used a weighted linear aggregation rule (WLC), and neglected other decision strategies [29]. OWA is a family of multi-criteria aggregation procedures. It has been developed in the context of fuzzy set theory. It involves two sets of weights: the weights of criterion importance and the order weights. By changing the order weights, one can generate a wide range of outcome. OWA provides an extension and generalization for the two fundamental classes of decision rules in the GIS: the Boolean overlay operations and the WLC procedures [26]. Both ANP and OWA with fuzzy quantifiers have been implemented individually in GIS environments (e.g. [26 – 33]). While each of these MCE procedures has proven to be very useful, however, they do not operate in the same level. The ANP is a global tool for analyzing the whole decision-making process, creating a network model of it and then evaluating each alternative with respect to this network. The evaluation process in the ANP uses a simple WLC to calculate the local scores of each alternative as a cell (raster format) or a polygon (vector format). The OWA operators, on the other hand, provide a very general framework for making the kinds of local aggregations used in the ANP. In 2013, Eldrandaly [18] introduced a new GIS-based multi-criteria evaluation procedure by extending the ANP using fuzzy quantifiers-guided ordered weighted averaging (OWA) operators, suggesting that the capabilities of ANP as a comprehensive tool for decision making can be improved by integration of the fuzzy linguistic OWA operators. This procedure allows decision-makers to define a decision strategy on a continuum between pessimistic (risk-averse) and optimistic (risk-taking) strategies. By changing the linguistic quantifiers, the GIS-based ANP-OWA can generate a wide range of decision strategies taking into accounts the level of risk the decision-makers wish to assume in their MCE. The GIS-based ANP-OWA procedure is composed of five major steps [18]: (1) Network model construction, (2) Pairwise comparison

and priority vectors, (3) Supermatrix formation, (4) Select linguistic quantifiers, and (5) Calculation of the overall evaluation score of alternatives. Detailed descriptions of this procedure are reported elsewhere [18].

#### IV. PROPOSED SPATIAL DECISION SUPPORT SYSTEM

To implement the proposed spatial decision making framework, a prototype intelligent GIS-based spatial decision support system (Tourism Site Selection Advisory System) is developed using Microsoft® Component Object Model (COM) technology. The COM is a standard that enhances software interoperability by allowing different software components, possibly written in different programming languages, to communicate directly [34]. A number of COM-compliant software packages are used to develop the proposed system.

The Visual Rule Studio® (an object-oriented expert systems development environment for windows) is used for developing the expert system component as an ActiveX DLL to achieve the required software interoperability. Visual Rule Studio solves the problem of software interoperability by allowing the developers to package rules into component reusable objects called RuleSets. By fully utilizing OLE and COM technologies, RuleSets act as COM Automation Servers, exposing RuleSet objects in a natural COM fashion to any COM compatible client. Visual Rule Studio installs as an integral part of MS Visual Basic, Professional or Enterprise Editions, and appears within the Visual Basic as an ActiveX Designer. This allows the developers to add rule objects to their existing or new Visual Basic application in much the same manner they would extend their application with a new form or ActiveX control. RuleSets can be compiled within Visual Basic. EXE, .OCX, or .DLL executables and used in any of the ways the developers normally use such executables. The RuleSet of the proposed system consists of 5 Classes and 198 Rules. The knowledge base for the expert system were acquired from various information sources including published studies and texts; technical reports; municipal ordinance and documents; and human expertise from selected professionals who have considerable experience in planning practices related to tourism facility sitting decisions. The inference engine of Visual Rule Studio's production system acts as the unseen hand or executor which causes processing to take place. In the proposed expert system forward chaining engine is used. Starting from an initial or current set of data, the forward chaining inference engine makes a chain of inferences until a goal is reached [35, 36].

The ArcGIS® Desktop 9.3 is used to manage the spatial data and to conduct the required spatial analysis operations. ArcGIS is a scalable set of state-of-the-art software for geographic data creation, management, integration, analysis, and presentation. It is built on a technology framework known as ArcObjects. ArcObjects is a set of platform-independent software components, written in C++, which provides services to support geographic information system (GIS) applications on the

desktop in the form of thick and thin clients and on the server. ArcObjects makes use of the Microsoft Component Object Model (COM). Detailed descriptions of ArcGIS are reported elsewhere [38, 38]. Visual Studio 2005 (C# Programming Language) and ArcObjects (ArcGIS development platform) libraries are used to develop the ANP-OWA module as an extension to ArcGIS. Extensions are a collection of toolbars and commands. Detailed descriptions of ArcGIS programming can be found elsewhere [39].

#### V. CASE STUDY: TOURIST HOTEL SITE SELECTION

This section presents the results of implementing the proposed system on a test regional area. The test problem utilized a real regional site (the north west of Asir Region, Saudi Arabia). This site is characterized by its mountainous nature with heights reaching 2700m above sea level. Mountains chain extends in a north-south direction with very steep slope and cliffs in the west, and generally gentle slope to the east with some high mountains. Vegetation is covering many parts of the place with dense patches of forest in various locations. The goal of the test problem is to identify the most suitable sites for a tourist hotel. The required GIS data layers (criterion maps) were extracted from a QuickBird satellite image and a 30m ASTER Global Digital Elevation Model. This study focused on employing a relatively small number of well-defined principles rather than taking into account extensive cases in obtaining and organizing the decision criteria, the map layers, and the experts' rules. However, since the system was designed as a scalable prototype, it can easily be adapted to any specific situation or needs with minor modifications and refinements.

In order to identify the most suitable sites for a tourist hotel, the current case study involves evaluating a set of sites on the basis of four objectives: market related, environmental, legal, and financial. These objectives are measured in terms of eleven attributes: (1) Accessibility, (2) Cultural Attractions, (3) View, (4) Distance from Sight Line, (5) Slope, (6) Ecosystem, (7) Landscape, (8) Land Use, (9) Surrounding Land Use, (10) Land Price, and (11) Existing Infrastructure. There are dependencies between market related, environmental, legal, and financial objectives, and between attributes belonging to these objectives. The overall goal here is to identify the most suitable sites for building a new hotel.

To solve this sitting problem, the three procedural steps of the proposed framework will be followed. The proposed system is executed by clicking on the Tourism Site Selection Advisory System button on ArcMap. Upon execution of the System, it gives the user three options: (1) Selection Criteria Advisory System, (2) Data Standardization, and (3) Multicriteria Evaluation (ANP-OWA) as shown in Fig. 2.



Fig. 2. Tourism Site Selection Advisory System.

5.1. Defining the sitting criteria

Upon starting the Selection Criteria Advisory System, the expert system asks the user to define the proposed tourism facility type. Then the expert system presents the recommended sitting criteria for the tourism facility under considerations (hotel). The decision maker has the option of either accepting or modifying these recommended criteria as shown in Fig. 3.

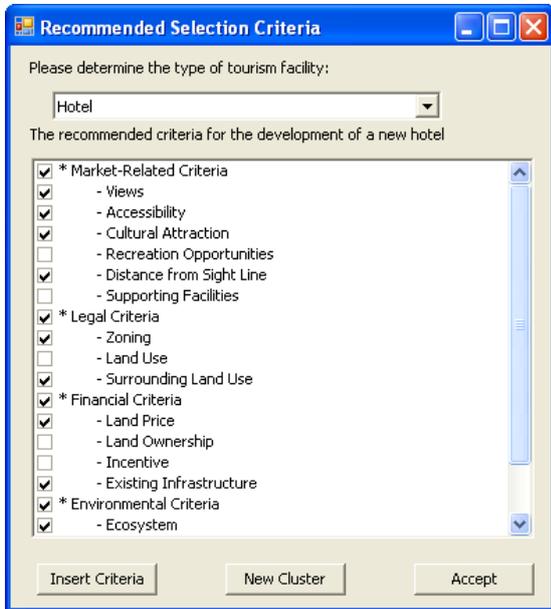


Fig. 3. Selection Criteria Advisory System

5.2. Data Standardization

After defining the sitting criteria, their corresponding criterion maps are created using raster format and each raster layer contains the attribute values assigned to the alternatives, and each alternative (cell) is related to the higher-level elements (i.e., attributes). Given a variety of scales on which each criterion can be measured, multicriteria evaluation requires that values contained in the various criterion map layers be standardized to a common scale. Thus before start building the ANP-OWA decision network of the current case study using the proposed system, the criterion maps must be standardized

using the data standardization function available in the System as shown in Fig. 4.

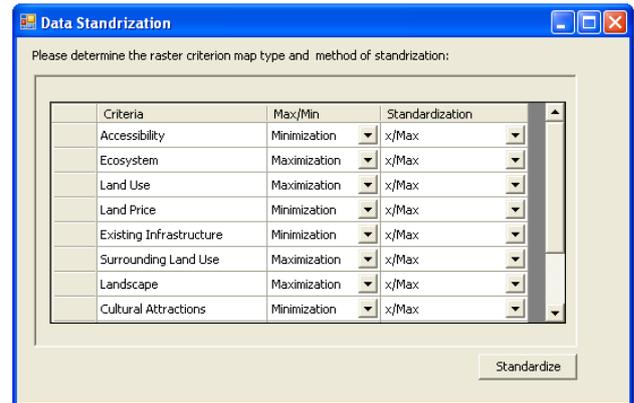


Fig. 4. Data Standardization

5.3. Multicriteria Evaluation

5.3.1. Network Model Construction

The first step in the ANP-OWA process is to construct a network model that captures the alternatives, the criteria and their relationships. In the context of this paper, a typical ANP network model for tourist hotel site selection is constructed as shown in Fig. 5. The developed model consists of a single control criterion (goal: hotel site selection), 4 criteria clusters (market related criteria, environmental criteria, legal criteria, and financial criteria), nodes (11 subcriteria or attributes related to the 4 criteria clusters), and alternatives. There are, in the model dependencies between the four criteria clusters, and between subcriteria belonging to these criteria clusters. Outer dependencies between two clusters are represented by a two-way arrow while inner dependencies among elements of a cluster are represented by looped arcs. To construct this model using the proposed system, the ANP-OWA procedure is activated by pressing the Multicriteria Evaluation (ANP-OWA) button. Then the suggested ANP Network model and the suggested dependency relationships are displayed, the decision maker has the option of either accepting or modifying them as shown in Fig. 6 and 7.

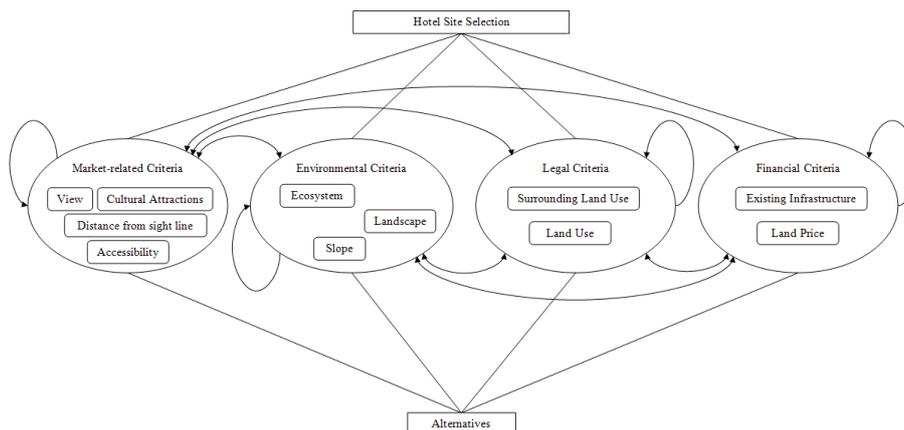


Fig. 5. Hotel Site Selection Network Decision Model

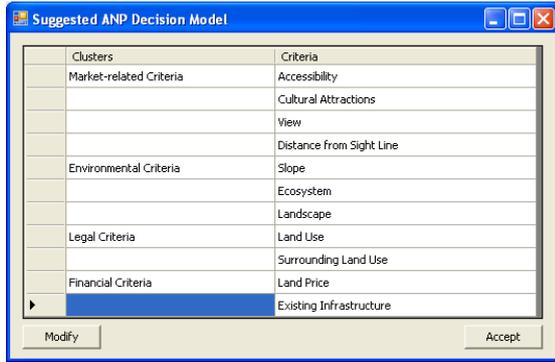


Fig. 6. Suggested ANP decision model

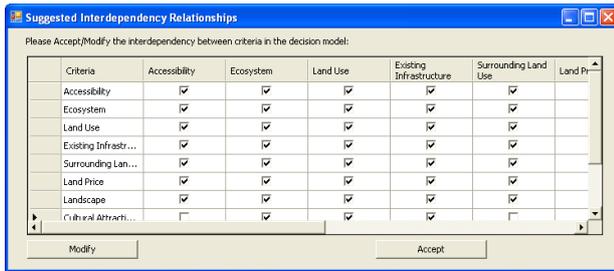


Fig. 7. Suggested dependency relationships

5.3.2. Pairwise comparison matrices and priority vectors

In ANP, similar to the comparisons performed in AHP, attributes (nodes) are pairwise compared with respect to their relative importance toward their control attribute according to interdependency between attributes (outer/inner) relationships. The attributes within the objectives (clusters) themselves are pairwise compared according to their influence on each attribute in another objective they are connected to (outer dependence) or attributes in their own objective (inner dependence). Influence may be evaluated in terms of importance, preference or likelihood taking a control attribute in mind. The objectives themselves are also pairwise compared with respect to their contribution to the goal (control criterion). Thus, there are two sets of weights,  $W_{k(j)} = (w_{1(j)}, w_{2(j)}, \dots, w_{l(j)})$  and  $W_q = (w_1, w_2, \dots, w_p)$ ,

are assigned to the attributes and objectives, respectively. The final weights of the attributes  $W_j = (w_1, w_2, \dots, w_n)$  are calculated using supermatrix operation as will be shown in section 5.3.3.

The relative importance values are determined with Saaty’s 1-9 scale. Similar to AHP, pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative importance with attributes (or objectives) being compared. The pairwise comparison matrix has the following form:  $A = \{a_{ij}\}$ , where  $a_{ij}$  is the pairwise comparison rating for element  $i$  and element  $j$ . The matrix  $A$  is reciprocal - that is,  $a_{ij} = 1/a_{ji}$  - and all its diagonal elements are unity.

Local priority vector can be derived by solving (1):

$$A \times w = \lambda_{\max} \times w \tag{1}$$

Where  $A$  is the matrix of pairwise comparisons,  $w$  is the eigenvector, and  $\lambda_{\max}$  is the largest eigenvalue. A Consistency Index  $CI$  is used to measure the degree of inconsistency in the square matrix  $A$  (where,  $CI = (\lambda_{\max} - n)/(n - 1)$ ,  $n$  is the number of columns of matrix  $A$ ). Then the Consistency Ratio  $CR$  is calculated (where,  $CR = CI / RCI$ ,  $RCI$  is the consistency index of a randomly generated pairwise comparison matrix). Generally, a  $CR$  of 0.10 or less is considered acceptable, otherwise the matrix  $A$  will be revised to improve the judgmental consistency [40, 41].

After constructing the decision model of the problem, the relative weights for all criteria clusters and their related subcriteria are calculated using the pairwise comparisons. First, we perform the pairwise comparison between the four criteria clusters as shown in Table 2 and Fig. 8. The system will warn the decision maker when the Consistency Ratio ( $CR$ ) is not acceptable.

Table 2. Pairwise comparison matrix of the level of objective (clusters)

	Market-related Factors	Environmental Factors	Legal Factors	Financial Factors	Weight	CR
Market-related Factors	1	2	2	3	0.429	0.005
Environmental Factors	0.5	1	1	2	0.222	
Legal Factors	0.5	1	1	2	0.222	
Financial Factors	0.333	0.5	0.5	1	0.127	

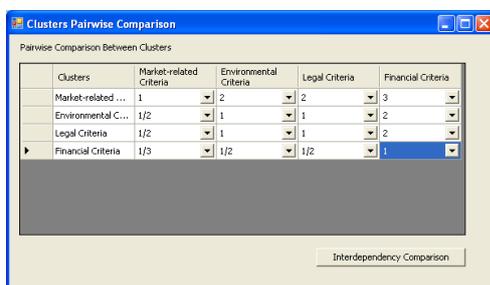


Fig. 8. Pairwise comparison between clusters

After finishing the Pairwise comparison process between the criteria clusters, we begin performing pairwise comparison between the subcriteria taking into account their interdependence relationships. For example, Fig. 9 demonstrating the connections between land price criterion and other subcriteria. Pairwise comparison procedures based on these connections are shown in table 3 and Fig. 10, 11, 12, and 13. Similarly, other subcriteria are also evaluated with 40 pairwise comparison procedures.

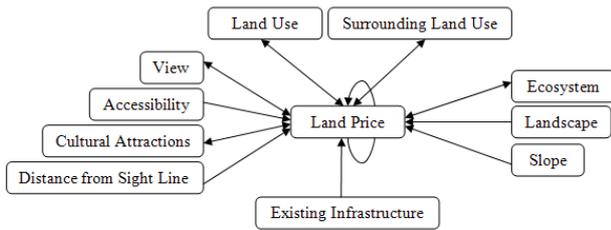


Fig. 9. Network Structure Regarding Land Price Criterion

Table 3. Pairwise Comparison Matrices Based on Land Price Factor

	Accessibility	Cultural Attractions	View	Sight Line	Weight	CR
Accessibility	1	3	2	2	0.429	0.005
Cultural Attractions	1/3	1	1/2	1/2	0.127	
View	1/2	2	1	1	0.222	
Sight Line	1/2	2	1	1	0.222	
	Slope	Ecosystem	Landscape	Weight	CR	0.009
Slope	1	3	2	0.545		
Ecosystem	1/3	1	1/2	0.168		
Landscape	1/2	2	1	0.287		
	Land Use	Surrounding Land Use	Weight	CR	Two Criteria!	
Land Use	1	1/2	0.333			
Surrounding Land Use	2	1	0.667			
	Land Price	Existing Infrastructure	Weight	CR	Two Criteria!	
Land Price	1	1/2	0.333			
Existing Infrastructure	2	1	0.667			

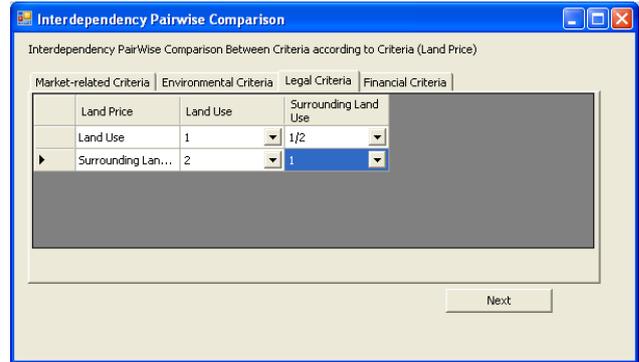


Fig. 12. Pairwise comparison between Legal Criteria according to (Land Price)

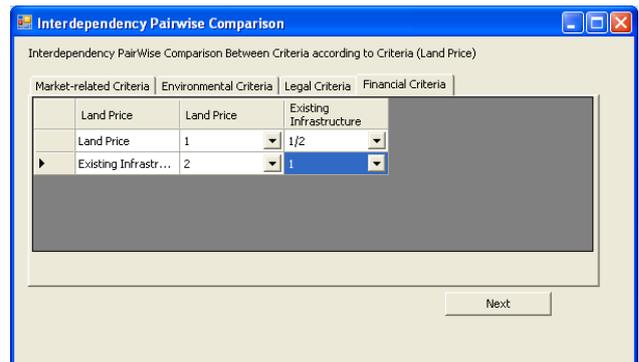


Fig. 13. Pairwise comparison between Financial Criteria according to (Land Price)

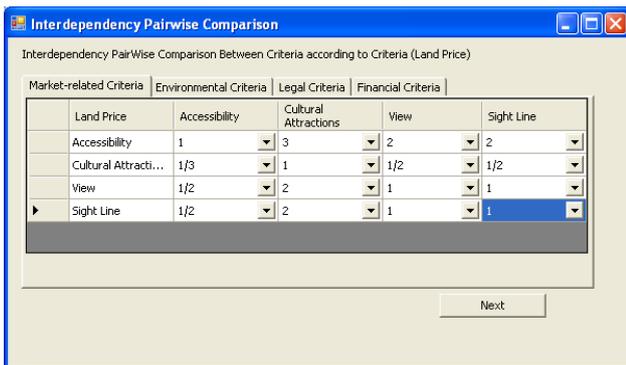


Fig. 10. Pairwise comparison between Market-related Criteria according to (Land Price)

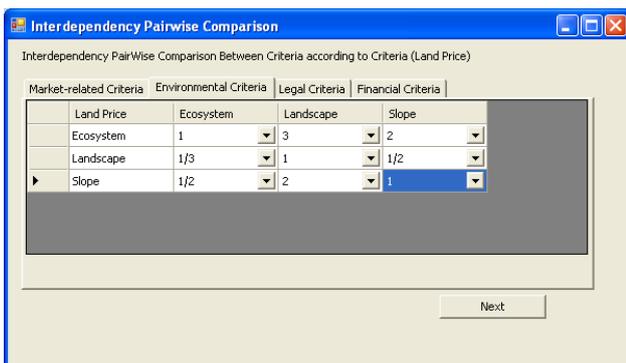


Fig. 11. Pairwise comparison between Environmental Criteria according to (Land Price)

5.3.3. Supermatrix formation

The supermatrix concept is similar to the Markov chain process [16]. To obtain global weights in a system with interdependent influence, the attributes local priority vectors obtained in section 5.3.2 are grouped and placed in the appropriate positions in a supermatrix based on the flow of influence from one objective cluster to another, or from an objective cluster to itself, as in the loop [42].

During this phase the following three supermatrices are obtained:

- Initial Supermatrix contains all the eigenvectors that are derived from the pairwise comparison matrices of the model (Table 4).
- Weighted Supermatrix obtained by multiplying the initial supermatrix values by the cluster weight matrix (Table 5)
- Limit Supermatrix obtained by raising the weighted supermatrix to the power of an arbitrarily large number (Table 6).

The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix are the same. The final weights  $W_j = (w_1, w_2, \dots, w_n)$  of all elements in the matrix can be obtained by normalizing each cluster of this supermatrix. Limit supermatrix exhibits the weights of criteria as shown in Table 7. Fig. 14 shows the final weights of both the clusters and their related criteria. The user has the choice to view the creation of different supermatrices by choosing show solution steps button.

Table 4. Initial Supermatrix

	Accessibility	Cultural Attractions	View	Distance from Sight Line	Slope	Ecosystem	Landscape	Land Use	Surrounding Land Use	Land Price	Existing Infrastructure
Accessibility	0.168	0.000	0.667	0.667	0.000	0.667	0.168	0.429	0.429	0.429	0.667
Cultural Attractions	0.000	0.168	0.000	0.000	0.000	0.000	0.000	0.127	0.127	0.127	0.000
View	0.545	0.287	0.333	0.000	1.000	0.333	0.545	0.222	0.222	0.222	0.000
Distance from Sight Line	0.287	0.545	0.000	0.333	0.000	0.000	0.287	0.222	0.222	0.222	0.333
Slope	0.545	0.000	0.287	0.667	0.333	0.545	0.545	0.545	0.545	0.545	0.545
Ecosystem	0.287	0.000	0.168	0.333	0.000	0.168	0.287	0.287	0.287	0.168	0.287
Landscape	0.168	1.000	0.545	0.000	0.667	0.287	0.168	0.168	0.168	0.287	0.168
Land Use	0.333	0.333	0.667	1.000	0.333	0.667	0.333	0.333	0.667	0.333	0.667
Surrounding Land Use	0.667	0.667	0.333	0.000	0.667	0.333	0.667	0.667	0.333	0.667	0.333
Land Price	0.000	1.000	1.000	0.000	0.000	1.000	0.000	0.333	0.333	0.333	0.000
Existing Infrastructure	1.000	0.000	0.000	1.000	1.000	0.000	1.000	0.667	0.667	0.667	1.000

Table 5. Weighted Supermatrix

	Accessibility	Cultural Attractions	View	Distance from Sight Line	Slope	Ecosystem	Landscape	Land Use	Surrounding Land Use	Land Price	Existing Infrastructure
Accessibility	0.072	0.000	0.286	0.286	0.000	0.286	0.072	0.184	0.184	0.184	0.286
Cultural Attractions	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.054	0.054	0.054	0.000
View	0.234	0.123	0.143	0.000	0.429	0.143	0.234	0.095	0.095	0.095	0.000
Distance from Sight Line	0.123	0.234	0.000	0.143	0.000	0.000	0.123	0.095	0.095	0.095	0.143
Slope	0.121	0.000	0.064	0.148	0.074	0.121	0.121	0.121	0.121	0.121	0.121
Ecosystem	0.064	0.000	0.037	0.074	0.000	0.037	0.064	0.064	0.064	0.037	0.064
Landscape	0.037	0.222	0.121	0.000	0.148	0.064	0.037	0.037	0.037	0.064	0.037
Land Use	0.074	0.074	0.148	0.222	0.074	0.148	0.074	0.074	0.148	0.074	0.148
Surrounding Land Use	0.148	0.148	0.074	0.000	0.148	0.074	0.148	0.148	0.074	0.148	0.074
Land Price	0.000	0.127	0.127	0.000	0.000	0.127	0.000	0.042	0.042	0.042	0.000
Existing Infrastructure	0.127	0.000	0.000	0.127	0.127	0.000	0.127	0.085	0.085	0.085	0.127

Table 6. Limit Supermatrix

	Accessibility	Cultural Attractions	View	Distance from Sight Line	Slope	Ecosystem	Landscape	Land Use	Surrounding Land Use	Land Price	Existing Infrastructure
Accessibility	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
Cultural Attractions	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
View	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158	0.158
Distance from Sight Line	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Slope	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
Ecosystem	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Landscape	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Land Use	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
Surrounding Land Use	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106	0.106
Land Price	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Existing Infrastructure	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088

Table 7. Calculated weights for the criteria

Criteria	Weights
Accessibility	0.173
Cultural Attractions	0.015
View	0.158
Distance from Sight Line	0.082
Slope	0.107
Ecosystem	0.050
Landscape	0.065
Land Use	0.116
Surrounding Land Use	0.106
Land Price	0.039
Existing Infrastructure	0.088

5.3.4. Select linguistic quantifiers

Zadeh [43] proposed the concept of fuzzy linguistic quantifiers. These objects are exemplified by terms such as most, many, some, “at least one”, or “all” and are represented by fuzzy sets [44]. Although there are several classes of quantifiers; Yager [45] suggested that the regular increasing monotone (RIM) relative quantifiers are the most adequate for multicriteria decision making as one wants to represent the fact that the larger the number of satisfied criteria the more satisfied we are with the solution. In this setting, if  $Q$  is a linguistic quantifier, then

it can be represented as a fuzzy subset over the unit interval [0, 1], where for each p in the unit interval, the membership grade  $Q(p)$  indicates the compatibility of p with the concept denoted by  $Q$  [24]. To identify the quantifier, Yager [45] employed one of the most often used methods for defining a parameterized subset on the unit interval:

$$Q(p) = p^\alpha, \alpha > 0 \tag{2}$$

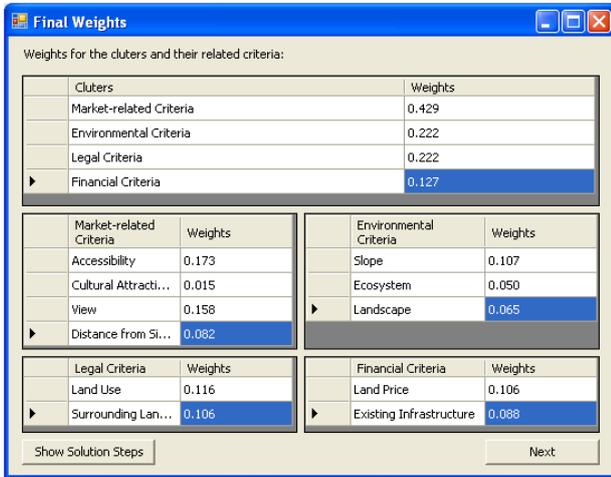


Fig. 14. The Final Weights of Decision Model

It can be applied for generating a whole family of the RIM quantifiers. Table 8 shows a selection of the RIM quantifiers and their characteristics. By changing the parameter,  $\alpha$ , one can generate different types of linguistic quantifiers and associated order weights between two extreme cases of the "All" and "At least one" quantifiers. With different sets of order weights, one can generate a wide range of OWA operators, including

the most often used decision rules in GIS: WLC, and Boolean overlay operations (AND and OR). Boolean approaches are extreme functions that result in risk-averse (pessimistic) solutions when the AND operator is used or in risk-taking (optimistic) solutions when the OR operator is used. The WLC approach is an averaging technique that softens the hard decisions of the Boolean approach, avoiding the extremes. In a continuum of risk, WLC falls exactly in the middle; it is neither risk-averse nor risk-taking as shown in Table 8 [27].

5.3.5. Calculation of the overall evaluation score of alternatives

After estimating the criterion weight  $w_j$  in section 5.3.3, the ordered criterion values  $z_{ij}$ , such that  $z_{i1} \geq z_{i2} \geq \dots \geq z_{in}$ , are obtained by sorting the standardized criterion values  $x_{ij}$  in descending order. Then the reordered criterion weight  $u_k$  is obtained according to the attribute value  $z_{ij}$ .

The overall score of the  $i^{th}$  alternative will be calculated as follows:

$$ANP - OWA_{(i)} = \sum_{j=1}^n v_j \cdot z_{ij} \text{ for all } i = 1, 2, \dots, m. \tag{3}$$

$$v_j = \left( \sum_{k=1}^j u_k \right)^\alpha - \left( \sum_{k=1}^{j-1} u_k \right)^\alpha \tag{4}$$

Where  $\alpha$  is the parameter linked to the linguistic quantifier.

Table 8. Selected linguistic quantifiers and corresponding  $\alpha$  parameters (adapted from [17])

$\alpha$	Quantifier (Q)	OWA weights ( $v_j$ )	Combination procedure	Trade-off	OR-ness	Decision strategies
$\alpha \rightarrow 0$	At least one	$v_1 = 1; v_j = 0$ for others	Logic "OR" (MAX)	0	1	Extremely optimistic
$\alpha = 0.1$	Few	*	*	*	*	Very optimistic
$\alpha = 0.5$	Some	*	*	*	*	Optimistic
$\alpha = 1$	Half	$v_j = 1/n$ for all j	WLC	1	0.5	Neutral
$\alpha = 2$	Many	*	*	*	*	Pessimistic
$\alpha = 10$	Most	*	*	*	*	Very pessimistic
$\alpha \rightarrow \infty$	All	$v_n = 1; v_j = 0$ for others	Logic "AND" (MIN)	0	0	Extremely pessimistic

Note: "\*" is Case dependent

The importance of the criteria has been judged and weights are calculated according to Tables 7. Given the weights and the corresponding standardized criterion maps ANP-OWA is applied using selected values of fuzzy linguistic quantifiers: at least one, few, some, half, many, most and all for the goal of the decision making as shown in Fig. 15. These linguistic quantifiers correspond to the following decision strategies: extremely optimistic, very optimistic, less optimistic, neutral, less pessimistic, very pessimistic, and extremely pessimistic as shown in Table 8. Fig. 16 shows the seven alternative land suitability scenarios for hotel site selection.

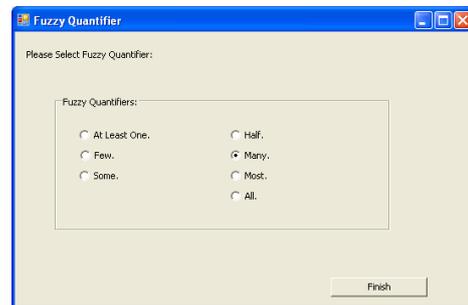


Fig. 15. Assigning linguistic quantifiers to the goal of a decision problem.

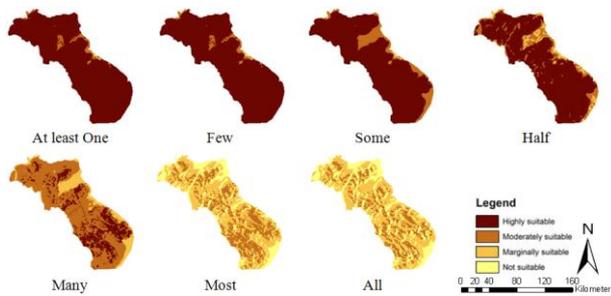


Fig. 16. Site suitability for hotel development: The results of ANP-OWA procedures for selected linguistic quantifiers.

## VI. CONCLUDING REMARKS

The tourism development site selection process has become increasingly complex because of the plethora of environmental laws and regulations as well as the greater public awareness and involvement in the zoning and environmental issues. Expert system, GIS and MCE are very vital efficient tools for solving sitting problem. However, each of these tools has its own limitations and drawbacks in solving such problem. The integration of these techniques eliminates these limitations and provides the decision maker with an innovative approach to sitting problem. Although many recent publications discussed the application of ES, MCE, and GIS in a variety of sitting problems, only a few of them are related to tourism development site selection problems.

This paper presents a new decision making framework in which ES, GIS, and ANP-OWA are integrated systematically to handle tourism development site selection decisions. According to the type of the proposed tourism facility, an expert system is used to define the recommended sitting criteria and the interdependence relationships within and between them. Then, the GIS-based ANP-OWA is used to perform the spatial data analysis necessary to generate a wide range of possible candidate sites' scenarios taking into accounts both the interdependence relationships between sitting criteria and the level of risk the decision-makers wish to assume in their multicriteria evaluation. A prototype spatial decision support system (Tourism Site Selection Advisory System) is developed to implement the proposed decision making framework. A typical case study is presented to demonstrate the application of the proposed decision making framework.

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