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# Possibility to Employ AHP as a Multi-Criteria Decision Making Method in Landscape Planning Initiatives

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Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/55885>

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## 1. Introduction

For Ersoy (2006), planning is a process set out to solve the problem. During planning, how and within what structural relationships this problem and/or problems have appeared, and how they can be resolved through interventions is analysed. A conceptual overview of plan and planning reveals that transformation of an intellectual model into a material design creates the "plan", and the entirety of the implementing process for realizing the plan constitutes "planning" (Akay, 2009). Planning is an all-round holistic action; contains social, economical, political, psychological, anthropological and technological factors; and is a multi-disciplinary, normative, democratic occupation and a professional engagement encouraging involvement and seeking action paths for options (Bulut and Atabeyoğlu, 2010). In brief, planning is deciding on the method for utilizing limited natural and cultural resources with a view to assuring and extending life quality (economical, social, psychological) of a country on national scale (Akay, 2009).

Parameters such as ensuring sustainable development, safeguarding natural resources, cost-effective nature of investments during the incorporation and operation process, stripping catastrophic nature of acts of God, availability to enhance types preferred in land utilization, etc. represent the generally disregarded, yet crucially significant facts in land utilization practices. Negligences and wrong practices along these issues lead to economical and social harm on individual and national scale, and unrecoverable loss of natural resources and cultural heritage. To avoid such losses, need to Physical Planning initiatives in depth of physical geography and relying upon ecological principles comes to sight (Turoğlu, 2005).

Sustainable use of natural and cultural resources, in other words, seating decisions for physical planning upon an ecologically acceptable base progressively gain weight in spatial

planning strategies today. In this sense, "landscape planning concept and practices" among other spatial planning strategies come to the forefront with its mediating and guiding attitude (Ayhan and Hepcan, 2009).

### 1.1. Landscape planning

Countries plan and reflect to the physical space their socio-economical decisions on national, regional and local scale for the development and enhancement of their societies. However, decisions for land utilization assuming various functions regarding residential areas influence economical actions in particular fields, and such actions consequentially induce adverse impacts in physical space as well as natural biotopes rising thereon such as the topography, soil, flora and fauna, and increasingly the ecological composition, culminating in environmental issues. Examining the topic from the standpoint of the benefit-cost theory reveals that, such decisions and practices yielding socio-economical benefits in the short run call forth adverse ecological costs driven by fading away natural assets with implications upon the whole society in the long run (Atabay, 1991).

According to Buchwald for the sake of preserving the efficiency and attributes of the nature, enhancing the skills for utilizing natural resources, the natural herbal and animal wealth, and human recreation in nature, landscape should be safeguarded within a sustainable framework. Landscape planning takes the following measures to assure the realization of these objectives: the optimal ecological-biological, visual composition and wealth of landscape is preserved and enhanced; cross-complementary zones precious for their ecological features are incorporated into the protected zones system, and plans suggesting optimal uses in ecological and visual terms where space utilization will have minimum impact on other uses are elaborated (Uzun, 2003).

The European Landscape Convention; describes "Landscape Planning" concept as the set of forward-looking actions launched to promote the value of, improve or construct the landscape (Anonymous, 2000). According to Başı (1998), safeguarding the nature and the land we live upon, availing of its existing potential in maximum, flourishing and then offering it to the benefit of future generations is only possible by exploring and scrutinizing the available use options that do not conflict with each other and implementing them based on a particular plan as buttressed by a consistent process maintenance and audit. Landscape planning targets, with reference to the idea favouring the flourishing of human-nature interaction as aligned to the balance between the process of protection and use, the construction of an environment promising healthy, free and high-quality life conditions to the society and its members (Benliay and Yıldırım, 2012). According to Ahern (2002), landscape planning is aimed at protecting rare, scarce and unique resources; avoiding the hazards; conserving limited resources through a controlled use; and identifying areas suiting development actions (Ayhan and Hepcan, 2009).

Analysing the definitions suggested by Başı, Buchwald and the European Landscape Convention reveals that some key concepts are stressed for landscape planning, and objectives are put forward across such concepts. The priority in this process is attached to

putting forward the balance between protection and use, analysing the ecological features, assessing the uses and therefore the ecological relationships, and then identifying the actions and construction of the environment that people can avail of to the utmost, yet that induces minimal damage to other organisms.

For Lewis (1964), McHarg, (1967), Buchwald et al., (1973), Hills (1976) and Kiemstedt, (1967), landscape planning is an instrument allowing to build up an efficient balance between human and nature in terms of protection and development. Landscape planning is aimed at addressing the interactive pattern between natural and cultural resources and the people utilizing them followed by incorporation of the same into the physical planning process; minimizing adverse impacts induced by environmental conflicts through the optimum land utilization approach, and supervising zoning initiatives to ensure optimum and proper maintenance of landscapes (Yüksel, 2003).

Landscape planning does not merely constitute a special planning for a landscape arrangement in rural or urban space, but represents the process of planning the measures for flourishing, conserving and maintaining both spaces as per the laws on ecology (Köseoğlu, 1982).

The fields of action for landscape planning and landscape management target securing sustainably the balance between protection and use throughout the human-nature interaction. Planning practices where the human-nature relationships and interactions are not properly analysed and assessed are among major factors that trigger environment issues (Şahin, 2009). The demonstrated understanding in the last century is that respecting a particular system and safeguarding the balance constitutes the condition precedent for the sustainability of life (clean and accessible water, air and food) in relationships with different systems. Natural resources that human needs to sustain life are limited to the capacity of the recycling mechanisms of those resources. Optimally utilizing the available resources, respecting the rights of future generations to utilize these resources and ensuring the sustainability of natural systems is a quite tough yet inevitable approach. What makes this approach tough is associated with the requirement to handle natural systems such that no damage should be induced to them throughout the entire range spanning from the initial phase of planning up to the construction, use, post-use and depletion phase (Çetinkaya, 2012).

To secure sustainable development, enhancing the environmental strategy, establishing a hierarchy of priorities for environment, and building efficient environmental policies in making decisions for investment are also needed besides economical and social policies.

In resolving the environmental issues, an ecology-based identification is needed with a view to setting up a hierarchy in the sustainable management of natural resources in relation to the type of solutions to be produced at the lower and upper scale. This is indeed "ecological land classification" adopted by myriad of European countries under different names including the bioregion, ecoregion, ecosystem classification, etc. Ecological land classification is a hierarchic classification of the space ranging from upper scale down to the lower scale. Setting up such a hierarchy owes to the assessment of different measures from

the upper scale down to the lower scale. The art of landscape ecology gaining a forward progress over the last years hierarchically divides landscape into various sub sections, and allows to make distinct comments on the structure, function and variation of landscape, and to identify zones in the sustainable ecological management (Uzun, 2003).

Landscape planning methods have greatly been enhanced in the course of time. Despite this however, like in all planning efforts, the planner should choose the most appropriate one among a plurality of distinct options impacted by a great number of factors in the landscape planning process. For the sake of obtaining a healthy decision support through a participatory approach, decision makers should compare and assess alternative land allocation forms according to the preferences, demands and expectations of the public, benefit-interest groups and sectoral specialists. Hence, alternative management strategies should be assessed in a multi-criteria pattern according to social, economical and environmental criteria through a participatory approach, and the most appropriate alternative should be chosen.

Such decision-making process may be quite complicated some time, therefore multi-criteria decision making methods are employed to minimize potential errors.

## **2. Multi-criteria decision making methods**

Key issue of the decision-making process is to choose the best alternative out of the alternatives set assessed by means of criteria competing and conflicting with each other (Saaty, 1986). Decision-making issue is typically choosing the most appropriate alternative out of the options set according to at least one objective or criterion. In this sense, if there is only one possible way to go, in other words if there is no possibility to make a choice, then there is no decision-making (Ünal, 2010).

Decision making is to identify and choose the alternatives that would deliver the desired condition. Decision is only the outcome of particular processes.

It is observed that decision highlights distinct aspects including the choosing action, alternatives conflicting with each other, and the process. From this point of view, we can define decision-making as the process of choosing the most appropriate one among alternatives conflicting with each other to satisfy a particular objective (Ünal 2010).

Decision making and planning concepts require the holistic perception of objectives, targets and strategies within a systematic understanding.

There are various methods, analyses and techniques employed to make informed decisions on case basis as long as the paths to follow for attaining these objectives, data sources, IT methods and other similar conditions vary.

Capability to make efficient decisions for directors owes to the use of scientific methods that can concomitantly assess myriad of qualitative and quantitative factors in the decision-making process. At the forefront of the methods that may be employed in this process is the

Multi-Criteria Decision Making method. The literature involves many studies where Multi-Criteria Decision Making methods are employed.

In the traditional multi-criteria decision making methods, final assessment of criteria and alternatives is expressed with real numbers and decision is made based on the customary "alternative fully satisfies the criteria or not" rationale. However, due to the complexity of the real life and our limited capacity of perception, there are various objects that we are unable to comprehend in absolute terms which can only be assessed through subjective opinions. Therefore, to cope with decision-making for complex objects, the general characteristic feature of the object (e.g. beauty) is handled as a fuzzy attribute, and then a set of attributes is defined where each attribute corresponds to a single criterion. Hence, while establishing the alternatives, the decision maker employs linguistic assets involving uncertainty based on his/her personal opinions which may be represented by fuzzy sets. Once such type of alternatives produced by the decision maker are assessed in a fully objective manner against the existing criteria, they are sorted and then the most appropriate one is identified, leading to the optimum solution (Eminov and Ballı, 2004).

It is possible to categorize by objective the huge bulk of multi-dimensional decision-making methods listed as decision-making methods in the literature in a plurality of forms based on various criteria such as optimization-consistency, reduction-classification, mathematics-statistics, etc. (Halaç, 2001). Accordingly, classification of multi-dimensional decision-making methods is shown in Table 1.

In case some sub-systems with logical ties between, yet considered different from each other are handled in the decision-making process, the objectives of each sub system should be consistent with the objectives of the master system (macro objectives), in other words, they should be aligned to inflexible objectives. In such a case, we can talk about consistency, and methods employed for this purpose are called Methods Aimed at Consistency. On the other hand, there are also planning methods where consistency is replaced by accessible and proper objectives. And these methods are called Methods Aimed at Optimization. Data Reduction Methods represent the methods that describe the variation of the dataset containing variables in  $p$  number, and aimed at defining the data structure through a fewer number of variables ( $k < p$ ) with no cross correlation. Classification Methods are the methods developed to facilitate to the actions for establishing prototype sets (groups, classes) for structures with unknown population characteristics, and further to assign new units to the preliminarily defined groups. Furthermore, most significant methods out of a vast set, each with a distinctive intended use, are discussed under the heading "Other Methods".

There are also some other decision-making techniques in addition to those covered by Table 1. However, Table 1 encompasses techniques that are commonly employed for various objectives. On the other hand, given the intended use and dominant properties of some techniques in Table 1, it is understood that they may be involved in multiple classifications. For instance, some techniques aimed at consistency (PERT and CPM, Input-Output technique, etc.) may also be used for optimization purposes as well through sensitivity analyses and dynamic analyses. To display this situation, one or more of the numbers from



<i>BY INTENDED USE METHODS</i>	<i>DECISION-MAKING TECHNIQUES</i>
1. METHODS AIMED AT CONSISTENCY  2. METHODS AIMED AT OPTIMIZATION	<ul style="list-style-type: none"><li>- The ELECTRE I Technique (2)</li><li>- Network Analysis and PERT/ CPM Techniques (1, 2)</li><li>- The Delphi Technique (2, 1)</li><li>- The Analytical Hierarchy Process (2)</li><li>- The Preference (Conjoint) Analysis (2)</li><li>- Simulation (1)</li><li>- Input- Output Analysis (1, 2)</li><li>- Dynamic Programming (2)</li><li>- Linear Programming (2)</li><li>- Goal Programming (2)</li><li>- Integer Programlama (2)</li><li>- Transport Models (2)</li><li>- Inventory Models (2)</li><li>- Markov Chains (1)</li><li>- Lagrange Factors (2)</li><li>- The Benefit-Cost Analysis (2)</li><li>- Quadratic Programming (2)</li></ul>
3. METHODS AIMED AT DATA REDUCTION	<ul style="list-style-type: none"><li>- Factor Analysis (3, 4)</li><li>- Correspondence Analysis (3)</li><li>- Discriminant Analysis (4)</li><li>- Clustering Analysis (4)</li><li>- Multi-Dimensional Scaling Analysis (3, 4)</li><li>- Multi-Dimensional Variance Analysis (5)</li><li>- Multi-Dimensional Regression Analysis (5)</li><li>- Canonical Correlation Analysis (5)</li></ul>
4. METHODS AIMED AT CLASSIFICATION	
5. OTHER METHODS (such as surveying the dependence structure, building hypotheses and hypothesis tests)	

(\*) Figures in parentheses denote the dominant intended use of the methods.

**Table 1.** Classification of Multi-Criteria Decision-Making Methods.

1 to 5 denoting the methodological class in which the technique has been involved according to its intended use have been supplemented to each technique in Table 1.

The decision analysis deals with using a rational process for choosing the best out of the alternatives. How "ideal" a chosen alternative is depends on the quality of the data employed to define the decision case. In this case, the decision-making process may be involved in one of the three classes below (Taha, 2000):

- a. Decision-making under **certainty** where data are deterministically known.

- b. Decision-making under the **risk** where the data may be defined through the breakdowns of possibility.
- c. Decision-making under **uncertainty** where the data cannot be assigned to relative weights representing the level of relationship in the decision process.

While data can be defined well under certainty, the data is fuzzy under uncertainty. Hence, decision-making under the risk is the "half-way" case.

In this section, the Analytical Hierarchical Process approach, one of the abovementioned models of decision-making under certainty will be discussed.

### 3. Decision-making under certainty

Linear programming methods is an example to decision-making under certainty. These methods are only suitable for cases that may be associated with mathematical linear functions where alternatives are well defined among each other. This section brings a different approach to cases where thoughts, ideas, senses and ambitions are measured such that decision alternatives are listed through a numerical scale. This approach is known as the Analytical Hierarchy Process (Taha, 2000).

#### 3.1. The analytical hierarchy process

The Analytical Hierarchy Process (AHP) is one of the multi-criteria decision-making methods defined by Thomas L. Saaty (1977). The AHS method imitates the mental action process for differentiating the groups intrinsically present in the human. The core essence of AHS is concept fragmentation and synthesis. Once the problem is fragmented into tiny integral bits, the system identifies the cross-significance of two elements compared as well as the magnitude of such significance. This system plays a critical role in human perception, concept formation, classification of examples and logical judgement (Cengiz, 2003).

It is observed that the AHS method is commonly employed to solve the complex multi-criteria decision-making problems. As a matter of fact, it is reported that, the process has been applied, since the date it was developed, to various decision-making problems in various fields including economy, planning, energy policies, resource allocation, health, resolution of conflicts, project selection, marketing, computer technology, budget allocation, accounting training, sociology, architecture and many else. Furthermore, there are examples as to the use of the method in complex environmental decision analyses too.

The AHS method is primarily a theory of measurement based on priority values yielded by the paired comparison of the elements. This method allows to consider both quantitative (objective) and qualitative (subjective) factors in choosing the best alternative. Thanks to its features such as simplicity, flexibility, ease of use and seamless interpretation demonstrated in the analysis of complex decision problems, the method seems to have a broad field of use in distinctive decision problems. In its current form, the method is interesting as one of the most popular multi-criteria decision-making methodologies today (Yılmaz, 1999).



The following steps are followed to solve a decision-making problem by means of the AHS method (Göksu and Güngör, 2008).

**Step 1:** A decision hierarchy is formed with the decision elements such that the decision-making problem is identified.

**Step 2:** The decision elements are compared on a pairwise basis between each other to yield a data set. While making pairwise comparisons, it is searched which of the two elements is more important and at what degree in decision making.

**Step 3:** The relative priority (significance, weight) values of decision elements is estimated by means of the eigenvalue method.

**Step 4:** Based on the relative priority of decision elements, general priority and sequence of decision alternatives is obtained.

### **Step 1: Hierarchical Model**

A complex system with many common characteristics, yet containing myriad of elements that are hard to concurrently consider can be simplified and more conveniently analysed by splitting them into sub systems. In this respect, by arranging the system in sequenced levels where each hosts different number of elements or factors, hierarchies are obtained. These hierarchies are formed based on the assumption that system elements can be split into discrete sets. Therefore, a rational and systematic solution can be reached for the problems by assessing all factors with potential relevance.

The process of setting up the hierarchic model starts with placing the general objective of the problem on the top level. Then, criteria to be employed in the assessment of alternatives are identified, and arranged in a hierarchic layout. In this hierarchy, a level consisting of the criteria and the sub level(s) into which each criterion is split into sub-criteria are found. The decision alternatives of the problem are placed on the bottommost level of the hierarchy, so the hierarchy formation process is completed. Finally, the topmost level and the bottommost level of the hierarchy is associated with each other through intermediate levels (Yılmaz, 2004). Factors at the same level are defined independently from each other (Ejder, 2000).

Creation of the decision hierarchy would vary based on the number of hierarchic levels, the complexity of the problem, and the depth of detail needed by the person undertaking the analyses to solve the problem (Yılmaz, 1999).

### **Step 2: Determining Priority Values**

Once the decision hierarchy is created, relative significance or the priority value of each element (criteria, sub-criteria, alternatives, etc.) at different levels of the hierarchy should be identified. In the AHS method, first pairwise comparisons are performed for this purpose.

**Pairwise Comparisons:** An element at any level is the relative element of the immediately upper level. The degree of impact induced by such relative elements in the immediately

upper element is compared in pairs. Let's say  $C_1, C_2, \dots, C_n$  represents elements at any level, and let's say  $W_1, W_2, \dots, W_n$  is the priority of impact (weight) induced by that element in the upper element to which they are linked, where  $W_i$ , reflects the impact power/weight of  $C_i$  on its own relative upper element. To create the weight vector ( $W_i$ ), first  $n$  number of elements should be compared in pairs in terms of their impact on the respective upper element (Yilmaz, 2004).

In these pairwise comparisons; by asking questions like "what element is preferred more (is more significant) when element 1 and element 2 are compared to the respective upper element?" and "what is degree of preference placed in favour of the more preferred element compared to the other?", the decision maker is prompted to make a judgement.

The results of these comparisons are arranged in matrix form. The prioritization scale developed by Saaty (1998) used to convert the results of such pairwise comparisons in the matrix into numerical values is presented in Table 2.

The table shows numerical values suggested for verbal preferences expressed by the person undertaking the pairwise comparisons. This scale is employed to construct the pairwise comparisons matrix.

Judgement for Verbal Preference	Description	Numerical Value
Equal Preference	Two activities make equal contributions to the objective.	1
Partial Preference	Experience or judgement places partial preference in favour of one action to the other	3
High Preference	Experience or judgement places high preference in favour of one action to the other	5
Very High Preference	One action is highly preferred compared to the other and its dominance is conspicuous in practice.	7
Absolute Preference	Proofs relating to the preference of an action to the other are greatly reliable.	9
Average Values	Values falling between two successive judgements to be used when compromise is necessary	2, 4, 6, 8
Opposite Values	When an element is compared to the other, one of the values above is assigned. When the second element is compared to the first, it gains an opposite value.	

**Table 2.** The Pairwise Comparisons Scale Used for Preferences in the AHS Method (Saaty, 1980).

**Pairwise Comparisons Matrix:** Values obtained from pairwise comparisons are placed in a matrix called "*pairwise comparisons matrix*". Hence, a matrix like in (1) is obtained (Yılmaz, 2004):

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdot & \cdot & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & \cdot & \cdot & a_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & \cdot & \cdot & a_{nn} \end{bmatrix} \quad (1)$$

where;

A = Pairwise comparisons matrix, and

$a_{ij}$  = the significance of the  $i^{\text{th}}$  element to the  $j^{\text{th}}$  element compared to the upper element in the hierarchy.

The values of the pairwise comparison matrix satisfy the equation in (2) and such equation is called "*reciprocity function*" (Saaty, 1989).

$$a_{ji} = \frac{1}{a_{ij}} \quad (2)$$

For the pairwise comparisons matrix to be fully consistent, it should satisfy the condition in (3).

$$a_{ik} = a_{ij}a_{jk} \quad (i, j, k = 1, 2, \dots, n) \quad (3)$$

To satisfy this equation is quite difficult due to the fact that values are obtained relatively from pairwise comparisons. If the judgements of pairwise comparisons are absolutely consistent, in other words, if the equation above is satisfied, then the inputs of the A pairwise comparisons matrix will not include any error, allowing it to suggest the equation in (4).

$$a_{ij} = \frac{w_i}{w_j} \quad (i, j = 1, 2, \dots, n) \quad (4)$$

$w_i$  = the priority value for the element  $i$  as calculated through the pairwise comparisons matrix,

$w_j$  = the priority value for the element  $j$  as calculated through the pairwise comparisons matrix,

Diagonal elements of the pairwise comparisons matrix take the value of 1 (5).

$$a_{ik}a_{kj} = \frac{w_i}{w_k} \frac{w_k}{w_j} = \frac{w_i}{w_j} = a_{ij} \quad (i, j, k = 1, 2, \dots, n)$$

$$a_{ii} = 1 \quad (i = 1, 2, \dots, n) \quad (5)$$

Once the pairwise comparison matrices are constructed, the priority values (weights) of factors compared to the respective immediately upper factor are calculated with reference of the matrix data.

### Step 3: Calculation of Priority Values

Pairwise comparisons matrices are used to calculate the priority values. During this calculation procedure, consistency of pairwise comparison judgements should be considered. Various methods have been developed for this purpose.

For fully consistent matrices, it is specified that normalizing any  $j^{\text{th}}$  column of the matrix ( $j=1,2,\dots,n$ ) would yield the priority vector (Yilmaz, 2004). Accordingly, the priority vector is calculated as provided in (6):

$$a = \frac{a_{ij}}{\sum_{k=1}^n a_{kj}} \quad (i = 1, 2, \dots, n) \quad (6)$$

where;

$W_i$  = priority value for the element  $i$ ,

$a_{ij}$  = value of the  $i^{\text{th}}$  row and  $j^{\text{th}}$  column of the pairwise comparisons matrix.

As another method for the calculation of priority values, normalizing the sum of values in rows of the fully-consistent pairwise comparisons matrix is suggested. Such mathematical calculation is carried out as provided in (7):

$$W_i = \frac{\sum_{j=1}^n a_{ij}}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}} \quad (i = 1, 2, \dots, n) \quad (7)$$

On the other hand, the "*eigenvector method*" by Saaty is an important method as it suggests a measure for consistency towards pairwise comparison judgements. Descriptions on this method are presented below (Yilmaz, 2004);

The eigenvector corresponding to the highest eigenvalue of the pairwise comparisons matrix ( $\lambda_{\max}$ ) is the priority vector. This vector (8) is represented with

$$W = [W_1, W_2, \dots, W_n] \quad (8)$$

This eigenvector is also referred to as the right eigenvector. Each normalized element of this vector indicates a priority value estimate and also involves errors made during comparison. If  $W_i$  ( $i = 1, 2, \dots, n$ ) values are known, then pairwise comparisons are based on absolute measurements, and the pairwise comparisons matrix is absolutely consistent. So, where  $i, j, k = 1, 2, \dots, n$ , the following equation can be derived (9) and (10):

$$a_{ji} = \frac{W_j}{W_i} = \frac{1}{W_i/W_j} = \frac{1}{a_{ij}} \quad (9)$$

and

$$a_{ij} \frac{W_j}{W_i} = 1 \quad (10)$$

Summing based on  $j$  on both sides of the equation yields,

$$\sum_{j=1}^n a_{ij} W_j \frac{1}{W_i} = n \quad (i = 1, 2, \dots, n) \quad (11)$$

(11) Transferring  $1/W_i$  on the left side of the equation to the right side yields the following equation:

$$\sum_{j=1}^n a_{ij} W_j = W_i n \quad (i = 1, 2, \dots, n) \quad (12)$$

(12). This equation is composed as

$$W = [W_1, W_2, \dots, W_n] \quad (13)$$

where (13) being the priority vector composed as

$$AW = nW \quad (14)$$

(14) According to the matrix theory,  $W$  in this equation is the eigenvector of the pairwise comparisons matrix  $A$ . Solving this equation yields eigenvalues  $\lambda_1, \lambda_2, \dots, \lambda_n$  of the pairwise comparisons matrix.

Indeed, since  $a_{ij}$  is based on subjective judgements, deviations from the ideal  $W_i/W_j$  ratio occur. Therefore, the matrix theory brings two cases to the foreground:

First, where  $\lambda_1, \lambda_2, \dots, \lambda_n$  are eigenvalues,

$$AX = X\lambda \quad (15)$$

if  $a_{ii} = 1$  for every  $i$ , and the eigenvalue of the matrix  $A$  above satisfying the equation (15), then

$$\sum_{i=1}^n \lambda_i = n \quad (16)$$

Therefore, when the equation  $AW = nW$  is satisfied, only one out of the eigenvalues of the pairwise comparisons matrix  $A$   $\lambda_i$  has  $n$  value (equal to  $n$ ), and all other eigenvalues are zero. This means, when the matrix  $A$  is consistent, the highest eigenvalue of the matrix  $A$  ( $\lambda_{\max}$ ) is equal to  $n$  ( $\lambda_{\max} = n$ ).

Considering them all, if the diagonal elements of the matrix  $A$  ( $a_{ii}$ ) are 1, and if the matrix  $A$  is consistent, then it is concluded that variations in  $a_{ij}$  do not lead to a change in the highest eigenvalue ( $\lambda_{\max}$ ) near  $n$ , and that the remaining eigenvalues have values near 0. Once the pairwise comparisons matrix is actually obtained, the problem (17)

$$AW = \lambda_{\max} W \quad (17)$$

will be solved, yielding the  $W$  priority vector (eigenvector) satisfying this equation and constituting the unit vector.

**Estimating the Consistency Ratio:** While the significance or priority values of elements are calculated on the basis of the pairwise comparisons matrix in the AHS method, mistakes or

inconsistencies may occur since pairwise comparisons are based on subjective considerations. To measure this condition, the "Consistency Ratio" is employed in the AHS method.

To create a pairwise comparisons matrix with n elements suggested by the AHS method, obtaining (n-1) assessments is enough. Accordingly, other assessments may be made. As a matter of fact, if element X is twice the element Y, and has four folds of significance compared to element Z, then we may infer  $X = 2Y$ ,  $X = 4Z$ ,  $2Y = 4Z$  ve  $Y = 2Z$ .

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{18}$$

Matrix Size (n)	Random Index (RI)
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

**Table 3.** Random Index Values Variable by Matrix Size Used to Calculate Consistency Ratio in the AHS Method (Yılmaz, 1999).



In this matrix, if the significance of element Z compared to element Y is different than 2, than this pairwise comparisons matrix will be inconsistent. This fairly common condition does not constitute a major problem in solving the problem. While making assessments as to pairwise comparisons, if the decision maker merely refers to the (n-1) key assessment and neglects other assessments, then the pairwise comparisons matrix should be expected to be inconsistent. This is a very common case, however this does not lead to major issues in solving the problem (Cengiz, 2003). In this case, the matrix consistency ratio (1.20) is measured. Normalizing this measurement through the size of the pairwise comparisons matrix (n) is defined by Saaty as the consistency index-CI (1.18) (Ejder, 2000).

To calculate the Consistency Ratio, the "*Random Index (RI)*" values should also be known. These values have been constructed by randomly placing 100 matrices in each node of the 1-15 size matrices and then averaging the Consistency Ratios calculated according to the following formula. However, as the values of random indices increase with the growing matrix size, 500 random pairwise comparisons matrices have been formed for each matrix size of 11, 12, 13, 14 and 15, and calculations have been repeated. Hence, RI values by matrix size as shown in Table 2 have been obtained (Yılmaz, 1999).

$$CR = \frac{CI}{RI} \quad (19)$$

If this ratio (19) is zero, then the judgements of the decision maker are fully consistent. With this ratio approximating to 1.00, it may be argued that the pairwise comparisons matrix based on the decision maker's judgements are not rational and consistent, but random. Furthermore, a consistency ratio of 0.10 or less indicates that the results obtained are within acceptable limits (Taha, 2000).

#### Step 4: Determining General Priority Values

The last stage of the AHS method is to identify the general priority values of bottommost elements of the decision hierarchy (decision alternatives) in reference to the topmost general objective. For the sake of a description clarity, this may be illustrated on a sample three-level decision hierarchy as follows (Yılmaz, 1999).

The first level of the three-level decision hierarchy consists of a single element that represents the overall objective, and has a priority value of 1. Let's assume that the second level of this hierarchy consists of n elements and third level consists of m elements. Accordingly;

$W_h$  = Priority value of the element at the first level (overall objective),

$V_i$  = Priority values of elements at the second level ( $i = 1, 2, \dots, n$ ),

$W_{ij}$  = Priority values of j elements (decision alternatives) at the third level compared to the element i at the second level ( $j = 1, 2, \dots, m$ ),

$W_i$  = Priority values of decision alternatives in reference to the overall objective ( $i = 1, 2, \dots, m$ )

Since the priority value of the overall objective is 1, multiplication of this value to the priority values of elements at the second level will make no difference. In other words, the priority values of elements at the second level of the hierarchy will remain the same.

Hence, priority values of decision alternatives in reference to the overall objective are obtained by multiplying the priority value of each element at the second level of the hierarchy to priority values of subordinate elements at the third level, and then by summing such weighted values of the alternatives. This procedure may be illustrated in matrix form as follows (20):

$$\begin{bmatrix} W_{11} & W_{21} & \cdot & \cdot & \cdot & W_{n1} \\ W_{12} & W_{22} & \cdot & \cdot & \cdot & W_{n2} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ W_{1m} & W_{2m} & \cdot & \cdot & \cdot & W_{nm} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \cdot \\ \cdot \\ \cdot \\ V_n \end{bmatrix} = [W_1 \quad W_2 \quad \cdot \quad \cdot \quad \cdot \quad W_m] \quad (20)$$

By calculating the  $W_i$  general priority values, a solution is offered to solve complex decision-making problems. Hence, the highest of these priority values may also be treated as the best, in other words the decision alternative to be chosen.

#### 4. Conclusion

While previously associated with minor pollution issues together with short-term solutions aimed at eliminating them, environment today reveals itself as the entire set of natural, economical, social and cultural values. Comprehending this fact has triggered the abandonment of traditional development models and exploration towards new models. Therefore, the traditional unlimited development and unlimited consumption models have started to be replaced by sustainable and more balanced development models.

Safeguarding the nature and the land we live upon, availing of its existing potential in maximum, flourishing and then offering it to the benefit of future generations is only possible by exploring and scrutinizing the available use options that do not conflict with each other and implementing them based on a particular plan as buttressed by a consistent process maintenance and audit (Başal, 1998).

As a managerial instrument, Landscape Planning reveals the inventory and analysis of natural and cultural environment, and so ensures that optimum decisions can be taken for land utilization alternatives. It is clearly known today that analyses with single dimension or variable are not sufficient in solving complex problems like the landscape analysis. The major assumption in single-dimension analyses is to consider the impacts of other dimensions in the case as constant and study only one dimension (factor) every time. However, events and objects in the universe are formed not under the influence of only one factor, but under the collective influence of myriad of internal and external factors, and

reveal a complex nature. For this reason, events and objects should be defined not based on a single variable, but on myriad of variables and their collective impacts.

When decision makers encounter a complex system formed by interrelated components (resources, outputs proposed, constraints, etc.) in landscape analyses, they first endeavour to gain a thorough insight into the composition of this system. Hence, judgements and decisions made are rather informed. In landscape analyses, particularly in identifying the criterion weights of natural data, user opinions are of great significance. However, entities proposing to solve a complex decision problem may take different decisions despite employing the same method. The reason is that people have different value judgements. And different value judgements would lead to different priorities. In other words, different decision makers may attach different priorities to the components of the system. At this point, AHS comes up as a process distinguished from other decision making approaches as it directly considers the value judgements of different decision makers.

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