Expert Systems with Applications 37 (2010) 926–938

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

# Measures and evaluation for environment watershed plans using a novel hybrid MCDM model

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ARTICLE INFO

Keywords:
Attitudes toward environment watershed plans
Environment watershed plan effects
Analytical network process (ANP)
Multiple criteria decision-making (MCDM)
DEMATEL
Network relation map (NRM)

ABSTRACT

Although environment watershed plans have management and erosion control plans, public perception often focuses excessively on catastrophes. Environment plans are affected by many factors such as human life, property, safety, management, operations, maintenance, ecology, the environment, artificial structures, and climate control. The purpose of this paper is to qualitatively and quantitatively measure the environment watershed plan indexes and to achieve the aspired levels for these plan indexes. Previous efforts to evaluate the environment plans have assumed that the criteria are independent, but reality proves otherwise. Here, we use a novel hybrid multiple criteria decision-making (MCDM) model to address the dependent relationships among the criteria. Specifically, we combined the decision-making trial and evaluation laboratory model (DEMATEL) with the analytical network process (ANP) to calculate the relative weights of the criteria under interdependence and feedback. A real-life environment watershed problem is investigated to demonstrate the proposed novel hybrid MCDM model. We also propose a strategy to improve the criteria gaps for achieving the aspired levels for human life and safety.



## 1. Introduction

The US Environmental Protection Agency defines a watershed as “the area of land where all of the water that is under it or drains off of it goes into the same place”. John Wesley Powell defines it as “that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course…”. Environment watershed planning is very important because it affects human life and safety. Its requirements are particularly difficult to fulfill in a dynamic geography with earthquakes, typhoons, and torrential rains. The commonly used measurements in environment watershed performance are storm water level and improvement during catastrophes, urbanization of land and the monitored rate (Adhityawarma & Trauth, 2007; Byun, Myers, & Marengo, 2005; Chen, Lien, Yang, Tzeng, & Liang, 2008a; Chen, Lien, Tzeng, & Yang, 2008b, 2009a; Chen, Lien, Tzeng, Yang, & Yen, 2009b; Sara et al., 2000), forestation or vegetation in watersheds (Karibu et al., 2006), forest ecosystems, and environmental changes (Kohyama, Canadell, Ojima, & Pitelka, 2005), a storm water retrofit plan for the mimico creek watershed (Li & Banting, 1999). These measurements only represent a small portion of the scenario, with over 90% of the “latent” events not reflected by them. Another way of looking at watershed planning is within a multiple criteria decision-making (MCDM) framework characterized by multiple conflicting criteria (Hwang & Yoon, 1981). The government has been forced to impose many plan regulations upon watershed management in an effort to reduce soil erosion. Watershed management and erosion control are also considered when new calamities or increased hydraulic structure quotas are applied to protect human life and safety. The proper evaluation of plan records has proved a challenge, however, as insufficient data makes objective assessment difficult.

We propose a novel hybrid MCDM model to solve these problems through an expert group. A decision-making trial and evaluation laboratory (DEMATEL) technique is used to detect complex relationships and build a network relation map (NRM) among criteria for environment watershed measurement and evaluation. An analytic network process (ANP) was used by Saaty (1996) to overcome the problem of dependence and feedback among criteria or alternatives. This is a general form of the AHP that releases the hierarchical structural restrictions. However, in the decision-making structure of AHP models, a unidirectional hierarchical relationship

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0957-4174/$ - see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.eswa.2009.04.068

among decision levels is adopted. Furthermore, the ANP of NRM does not require a strictly hierarchical structure but uses a ratio scale formed by human judgments instead of arbitrary scales. Using ratio scales to capture all kinds of interactions and human judgments, assessing dispatching rules for wafer fabrication, and making accurate predictions through the use of these scales is what makes ANP a powerful method (Chung, Lee, & Pearn, 2005; Lin, Chiu, & Tsai, 2007; Tuzkaya, Onut, Tuzkaya, & Gulsun, 2008). Since ratio scales are a fundamental kind of number amenable to performing the basic arithmetic operations of adding within the same scale and multiplying different scales meaningfully as required by the ANP (Saaty, 2003), it also makes it possible to measure all tangible and intangible criteria in the model. Here, DEMATEL is used in combination with ANP to construct a new plan measurement model. The qualitative and quantitative measurements of the comprehensive conservation are used to build the environment watershed plan system indexes and to achieve the aspired levels in these plan system indexes.

An empirical case is used to demonstrate how the new hybrid MCDM model can be used to analyze an environment watershed plan. Since this study is a discussion of how the criteria/factors affect environment watershed plans, our study surveys watershed experts who have knowledge or experience in environment watersheds in order to measure the performance of environment watersheds. There are several objectives of good environment watershed planning: First, reduce water sand calamity to lose and protect lives and property. Second, safeguard the ecosystem, which gives consideration to people and natural equilibrium development in order to maintain good environmental quality. Third, monitor the environment around water collection districts and enforce good construction methods in order to balance the quality of the environment with development. Fourth, use the water and soil resources rationally. We need to maintain the health of water collection districts in order to achieve sustainable development.

The proposed model could be used to evaluate the effectiveness by finding the central criteria for evaluating and illustrating criteria interrelations based on NRM and by finding elements to improve the effectiveness of environment watershed plans and make strategic target plans. Moreover, the results show that the effectiveness calculated by the proposed model is consistent with that from DEMATEL and ANP.

The remainder of this paper is organized as follows. Section 2 summarizes some important previous research. We introduce the environment watershed effect measurements, determine the influential factors of environment watershed effectiveness, and establish the research hypotheses by a literature review. In Section 3, a brief introduction of DEMATEL and ANP techniques is given. We establish a novel hybrid model using these methods. In Section 4, an empirical study of an environment watershed plan is shown using the proposed evaluation model. The results are discussed and compared with the traditional additive evaluation model. Section 5 concludes with remarks.

## 2. Environment watershed plan measurements

What is a watershed? Component landforms that commonly occur in a watershed include steam channels, floodplains, stream terraces, alluvial valley bottoms, alluvial fans, mountain slopes, and ridge tops (Petersen, 1999). Environment watershed plan measurements involve a number of complex factors, however, including management engineering, ecological restoration, environmental construction, and environmental conservation issues. In the past, a plan dimension index could be based simply on the aggregate environment engineering of the catastrophe rate for a period of time or landing cycles, but this may be incomplete. Yeh and Lin (2005) suggested that the merging of ecological engineering measures into the framework of watershed management became one of the most crucial research topics for our local authority institutions. We must simultaneously consider many factors/criteria; the environmental watershed plan index focuses on catastrophe, human safety, comfort, interest, the ecological system, and environmental sustainability (Chen et al., 2008a, 2008b; Chen et al., 2009a, 2009b). Many studies have provided useful methodology and models based on problem-solving procedures that have mainly been applied to the field of environment watershed plan management in Taiwan and the rest of the world. Watershed planning, restoration, and management have specific hydrologic functions and ecological impacts. The inventory, evaluation, and planning for watershed restoration were based on geomorphic, hydrologic, and ecological principles. This is a natural approach to watershed planning that works with nature to restore degraded watersheds (Petersen, 1999). The operation procedures of several key model components, participation of local communities, utilization of geographical information systems, investigation and analysis of the ecosystems, habitats, and landscapes, and allocation of ecological engineering measures are illustrated in detail for a better understanding of their values in the model (Chen et al., 2008a, 2008b, 2009a, 2009b; Yeh & Lin, 2005; Özelkan & Duckstein, 2002). In the Austrian Danube case study, there are 12 alternatives and 33 criteria. The criteria mainly include three conflicting types of interest: economy, ecology, and sociology. Apart from calamity, which still accounts for environment watershed planning in natural catastrophes, engineering design error and incident data, maintenance, and operational deficiencies are typically cited as causes of failed planning. It has been suggested that "proactive" plan measures be instituted, especially while monitoring human-error-related engineering design errors. This study aims to discuss the effects and produce a NRM for each factor/criterion. Influence factors/criteria and the relational structure of environment watershed planning has been studied. So that each influence constructs surface and factor/criterion through present situation investigation, experience rule, literature review, and expert interview income after the preliminary result by counting important degree analysis after screening the result of the income. Meanwhile, based on several evaluation criteria considered for environment watershed plan effectiveness, this paper uses two methods to establish the evaluation model based on a new hybrid MCDM model to address dependent relationships among criteria, using a Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique to build a NRM, then an ANP technique is used to obtain the relative importance/weighting preferences for each criterion.

The environment watershed problems of the world have been statistically described from natural disasters and the artificial merging of two levels; in the first, typhoons, torrential rains, and earthquakes cause the rivers to overflow, cause the violent perturbations in landslides, and result in potential debris flow. In addition, environmental demand for space and water has increased in artificial disturbances due to population expansion, so that changes in land pattern utilization and terrain features carry out the transition of development. This also leads to the destruction of road water and soil conservation, devastation of the environment, damage to biological habitats, pollution of rivers and creeks, a threatening of fish species, loss of forest cover, erosion, and urban growth, among other things. What can we do to solve the environmental watershed problems? Firstly, from the watershed environment survey data, we found characteristic values that improve and stabilize the river canal shape, increase the activities of the biological community, habitat mold, and regeneration, structure the integrity of the ecological corridor, and create peripheral landscape and natural environment features. In summary, we need to consider intact factors/criteria that include four influence aspects

**Table 1**
The Influence Dimensions and Criteria for Comprehensive Conservation in Watershed Environment.

| Dimensions | Influence criteria | Statements of influence criteria |
|---|---|---|
| Watershed management and erosion control ($D_1$) | 1. Violent landslide perturbations ($C_1$) | In order to reach the purpose of stabilizing landslide, use various kinds of projects and nonprojects to increase soil body resistance |
| | 2. Potential debris flow torrents ($C_2$) | Renovate the potential debris flow torrent and set up the mechanism of safe protection to reach the effectiveness of disaster prevention and mitigation |
| | 3. Rivers of erosion and deposition ($C_3$) | Treat channel silt situations, the coherent abilities of every bottleneck section, and the sources of soil and sand, and then put forward the solution |
| | 4. Soil and water conservation of roads ($C_4$) | Improve on the issues of the slope stability destroyed by road development and the conservation of water source to reduce the impact produced by roads toward environment |
| Ecological restoration ($D_2$) | 5. Activities of biological communities ($C_5$) | Investigate biological species and habitat environment of watershed to understand the combination of regional ecology |
| | 6. Habitat molds and regeneration ($C_6$) | Consider the ecological development in watershed to improve the environment of ecological habitat |
| | 7. Integrity of ecological corridors ($C_7$) | Set up ecological protection plan and draw up the largest coverage of human activity and the buffer between people and living beings to maintain the continuity and fullness of ecological corridor |
| | 8. Ecological monitoring and management ($C_8$) | Continuously monitor ecological quantity and species development in the area, improve and investigate possible reasons of influence (water quality, air and offal) |
| Environmental construction ($D_3$) | 9. Ecological potentiality and restriction ($C_9$) | Analyze the issues of biological resource, water quality resource, and ecological resource |
| | 10. Peripheral landscapes and natural features ($C_{10}$) | Wholly consider the combination of tour landscape and special features in inside and outside planning districts |
| | 11. Tour facilities ($C_{11}$) | Emphasize the harmoniously aesthetic feeling of ecological environment and every facility should take natural material as the core |
| | 12. Resources of humane industries ($C_{12}$) | Lead local humane style and peculiar products (such as culture, fruit, and animal) in the wholly humane industry plan |
| | 13. Potentiality of land development ($C_{13}$) | Through considering the traffic convenience and the susceptibility of hinterland size and calamity, set up the development potentiality of regional construction |
| Environmental conservation ($D_4$) | 14. Artificial disturbance minimization ($C_{14}$) | Artificial disturbance minimizing makes the natural ecology reach the balance |
| | 15. Prevention of development ($C_{15}$) | Delimit the preserve of watershed and forbid developing |

and fifteen factors/criteria. The four influence aspects are (1) watershed management and erosion control, (2) ecological restoration, (3) environmental construction, and (4) environmental conservation. The fifteen factors/criteria are (1) violent landslide perturbations, (2) potential debris flow torrents, (3) rivers of erosion and deposition, (4) soil and water conservation of roads, (5) activities of biological communities, (6) habitat molds and regeneration, (7) integrity of ecological corridors, (8) ecological monitoring and management, (9) ecological potentiality and restriction, (10) peripheral landscapes and natural features, (11) tour facilities, (12) resources of humane industries, (13) potentiality of land development, (14) artificial disturbance minimization, and (15) prevention of development. These are given in Table 1.

## 3. Building a novel hybrid MCDM model for environment watershed plan

In Section 2, this paper establishes a watershed environmental plan system that will exert an influence in the watershed environment. When the government, educational circles, and industry work together and plan at the same time, they will collect the relations and different literary composition dimensions and criterion of the watershed environment and produce some impact on the watershed environment. Thus, a watershed environmental plan must consider in detail watershed management and erosion control, ecological restoration, environmental construction, and environmental conservation. It can be difficult to quantify precise values in such complex evaluation systems. A complex evaluation environment can, however, be divided into subsystems to more easily judge differences and measure scores. Thus, the relationship of a network structure and the degree of interdependence are determined from the results of the DEMATEL technique. Subsequently, we employ ANP to obtain the weight of each perspective (criterion).

### *3.1. Clarifying interrelations between criteria*

In a complex system, all criteria are related, either directly or indirectly, making it difficult to define a specific objective/aspect in isolation. While the vision of an interdependent system can lead to passive positioning, a clear hierarchical structure can lead to linear activity, with no dependence or feedback, which may create new problems (Tzeng, Chiang, & Li, 2007).

Study for explore nature and research that quantize, so-called quantization it studies to be every problem quantity, probe into issue their through difference of quantity, and method, question of quantity, research this utilize way of questionnaire go on. Quality research requires probing into the characteristics of the definition, way, or metaphor and researching the quality that is designed to be a problem for every criterion, go on through way, expert interviews to analyze. Its purpose lies in that it is relevant for the environmental watershed plan program to probe into that resident's life for comfort, life security, and ecological conservation of the environment. The influence continues in the local environment for sustainable development by looking for and going against its influence degree, and then we must set up some basic concept tactics with these questions. Our research utilizes, comments, and allows the decision method to be the main analysis tool.

In Section 2, we discussed environmental watershed program and environment's sustainable development to construct dimensions and 15 criteria with four dimensions to influence as we have seen through previous research. Through the research of quantization, it influences the weight in the environmental watershed program and assesses the comprehensive performance to influence degree and every criterion which the environmental watershed program probes into every criterion. It is construct dimensions and improving four based on scheme direction of research basically to put forward to set up after the pluses and minuses to understand.

The main analysis tool that this research institute uses is DEMATEL with the ANP method; the purpose of using its analytical method is as follows: (1) use DEMATEL to construct the affirmation that influences the relationship among criteria; (2) probe into and look for an offering to influence the resident's life to be compatible with the watershed environmental plan through documents, the ecological restoration of life security, environmental construction and conservation, and the environmentally sustainable development of criterion; and (3) point out in previous research the watershed management and erosion control, ecological restoration, environmental construction, and environmental conservation that connects with each dimension and criterion. However, the part mentioned in documents has not been completed yet. Thus, we utilized DEMATEL to construct the affirmation of the influence relationship among the dimensions and criteria (Chiu, Chen, & Tzeng, 2006; Huang, Tzeng, & Ong, 2005; Liou, Tzeng, & Chang, 2007, 2008; Tzeng et al., 2007) and then utilized ANP to evaluate the weight (Saaty, 1996). Next, we utilized ANP to determine the weight and performance value. After we finished getting related after the affirmation, we used ANP to go on every weight criterion to calculate (Saaty, 1996). We influenced the resident's life to be compatible while the watershed environmental plan in the ink district through ANP understands. The weight that the life security and ecological restoration of the environment are replied and bred and the environmentally sustainable development criterion and influence degree utilize five measure forms to carry on the comprehensive performance and to assess the performance value at the same time, later arranged in order.

### 3.2. DEMATEL technique for building a network relation map (NRM)

The DEMATEL technique was used to investigate and solve the complicated problem group. DEMATEL was developed with the belief that the pioneering and proper use of scientific research methods could help to illuminate specific and intertwined phenomena and contribute to the recognition of practical solutions through a hierarchical structure. The methodology, according to the concrete characteristics of objective affairs, can verify interdependence among variables/attributes and confine the relationship that reflects the characteristics with an essential system and evolution trend (Chiu et al., 2006; Huang et al., 2005).

DEMATEL has been successfully applied in many situations such as marketing strategies, e-learning evaluations, control systems, and safety problems (Chen et al., 2008, 2009; Hori and Shimizu, 1999; Liou et al., 2007; Ou Yang et al., 2008; Tzeng et al., 2007).

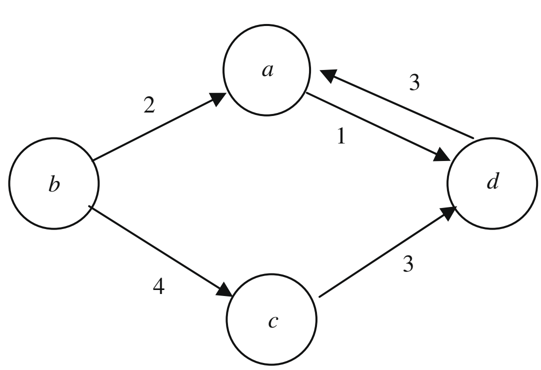


**Fig. 1.** The directed graph.

The method can be summarized as follows:

Step 1: *Calculate the direct-influence matrix by scores.* Based on experts' opinions, evaluations are made of the relationships among elements (or variables/attributes) of mutual influence using a scale ranging from 0 to 4, with scores representing 'no influence' (0), 'low influence' (1), 'medium influence' (2), 'high influence' (3), and 'very high influence' (4). The digraph can portray contextual relationships among the elements of the system, as shown in Fig. 1. For example, an arrow from $b$ to $a$ signifies that $b$ affects $a$, and the influence score is 2. They are asked to indicate the direct effect they believe a factor $i$ will have on factor $j$, as indicated by $a_{ij}$. The matrix $\boldsymbol{A}$ of direct relations can be obtained.

Step 2: *Normalize the direct-influence matrix.* Based on the direct-influence matrix $\boldsymbol{A}$, the normalized direct-relation matrix $\boldsymbol{D}$ is acquired by using formulas (1) and (2).

$$\boldsymbol{D} = k\boldsymbol{A} \tag{1}$$

$$k = \min\left\{1 \Big/ \max_i \sum_{j=1}^{n} a_{ij}, 1 \Big/ \max_j \sum_{i=1}^{n} a_{ij}\right\}, \quad i,j \in \{1,2,\ldots,n\} \tag{2}$$

Step 3: *Attaining the total-influence matrix T.* Once the normalized direct-influence matrix $\boldsymbol{D}$ is obtained, the total-influence matrix $\boldsymbol{T}$ of NRM can be obtained through formula (3), in which $\boldsymbol{I}$ denotes the identity matrix.

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + \cdots + \boldsymbol{D}^k \\ &= \boldsymbol{D}(I + \boldsymbol{D} + \boldsymbol{D}^2 + \cdots + \boldsymbol{D}^{k-1})[(I - \boldsymbol{D})(I - \boldsymbol{D})^{-1}] \\ &= \boldsymbol{D}(I - \boldsymbol{D}^k)(I - \boldsymbol{D})^{-1}\end{aligned}$$

Then,

$$\boldsymbol{T} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1}, \text{ when } k \to \infty, \quad \boldsymbol{D}^k = [0]_{n\times n} \tag{3}$$

where $\boldsymbol{D} = [d_{ij}]_{n\times n}$, $0 \leqslant d_{ij} < 1$, $0 < \sum_{j=1}^{n} d_{ij}$, $\sum_{i=1}^{n} d_{ij} \leqslant 1$. If at least one row or column of summation, but not all, is equal to 1, then $\lim_{k\to\infty} D^k = [0]_{n\times n}$.

Step 4: *Analyze the results.* In this stage, the sum of the rows and the sum of the columns are separately expressed as vector $\boldsymbol{r} = (r_1, \ldots, r_i, \ldots, r_n)'$ and vector $\boldsymbol{c} = (c_1, \ldots, c_j, \ldots, c_n)'$ by using formulas (4)–(6). Let $i = j$ and $i,j \in \{1,2,\ldots,n\}$; the horizontal axis vector ($\boldsymbol{r} + \boldsymbol{c}$) is then made by adding $\boldsymbol{r}$ to $\boldsymbol{c}$, which illustrates the importance of the criterion. Similarly, the vertical axis vector ($\boldsymbol{r} - \boldsymbol{c}$) is made by deducting $\boldsymbol{r}$ from $\boldsymbol{c}$, which may separate criteria into a cause group and an affected group. In general, when ($\boldsymbol{r} - \boldsymbol{c}$) is positive, the criterion is part of the cause group. On the contrary, if ($\boldsymbol{r} - \boldsymbol{c}$) is negative, the criterion is part of the affected group. Therefore, a causal graph can be achieved by mapping the dataset of ($\boldsymbol{r} + \boldsymbol{c}$, $\boldsymbol{r} - \boldsymbol{c}$), providing a valuable approach for decision-making.

$$\boldsymbol{T} = [t_{ij}]_{n\times n}, \quad i,j = 1,2,\ldots,n \tag{4}$$

$$\boldsymbol{r} = \left[\sum_{j=1}^{n} \boldsymbol{t}_{ij}\right]_{n\times 1} = [\boldsymbol{t}_{i\cdot}]_{n\times 1} = (r_1, \ldots, r_i, \ldots, r_n)' \tag{5}$$

$$\boldsymbol{c} = \left[\sum_{i=1}^{n} \boldsymbol{t}_{ij}\right]'_{1\times n} = [\boldsymbol{t}_{\cdot j}]_{n\times 1} = (c_1, \ldots, c_j, \ldots, c_n)' \tag{6}$$

where vector $\boldsymbol{r}$ and vector $\boldsymbol{c}$ express the sum of the rows and the sum of the columns from the total-influence matrix $\boldsymbol{T} = [t_{ij}]_{n\times n}$, respectively, and the superscript denotes the transpose.

### 3.3. Finding the preference of criteria weights by ANP based on NRM

ANP as an MCDM method can be used to evaluate the most suitable locations by systematically selecting the best facilities. The ANP is a relatively simple and systematic approach that can be used by decision-makers. MCDM techniques have also been widely used for the facility site selection problem. The ANP is an extension of AHP by Saaty (1996) that was developed to overcome the problem of interdependence and feedback among criteria and alternatives. Although the AHP and the ANP both derive ratio scale priorities by making pair-wise comparisons of elements (such as dimensions or criteria), there are important differences between them. The first difference is that the AHP is a special version of the ANP. The ANP handles dependence within a cluster (inner dependence) and among different clusters (outer dependence). Second, the ANP is a nonlinear structure, while the AHP is linear and hierarchical, with goals at the top levels and alternatives in the lower levels based on dynamic concepts of the Markov chain.

The initial step of the ANP is to compare the criteria in the entire system in order to form a supermatrix through pair-wise comparisons. This is done by asking "How much importance does one criterion have compared to another criterion with respect to our interests or preferences?" The relative importance is determined using a 1–9 scale, representing a range from equal importance to extreme importance (Huang et al., 2005). The general form of the supermatrix is shown in Eq. (7), where $C_m$ denotes the $m$th cluster, $e_{mn}$ denotes the $n$th element in the $m$th cluster, and matrix $\boldsymbol{W}_{ij}$ is the principal eigenvector of the influence of the elements comparing the $j$th cluster to the $i$th cluster. The form of the supermatrix depends on the type of structure. For example, if the structure of the system is an unweighted supermatrix $\boldsymbol{W}$ (Fig. 2), then the local priorities derived from the pair-wise comparisons are contained throughout the network is shown in Eq. (8).

$$\boldsymbol{W} = \begin{array}{c} \\ \\ C_1 \begin{array}{c} e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\ C_2 \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\ \vdots \\ C_m \begin{array}{c} e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{array} \end{array} \begin{array}{c} \begin{array}{ccccccc} C_1 & & C_2 & & \cdots & & C_m \\ e_{11} \cdots e_{1n_1} & & e_{21} \cdots e_{2n_2} & & \cdots & & e_{m1} \cdots e_{mn_m} \end{array} \\ \begin{bmatrix} \boldsymbol{W}_{11} & \cdots & \boldsymbol{W}_{12} & \cdots & \boldsymbol{W}_{1m} \\ \boldsymbol{W}_{21} & \cdots & \boldsymbol{W}_{22} & \cdots & \boldsymbol{W}_{2m} \\ \vdots & & \vdots & & \vdots \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}_{m1} & \cdots & \boldsymbol{W}_{m2} & \cdots & \boldsymbol{W}_{mm} \end{bmatrix} \end{array} \tag{7}$$

$$\boldsymbol{W} = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 0 & 0 & \boldsymbol{W}_{13} \\ \boldsymbol{W}_{21} & 0 & 0 \\ 0 & \boldsymbol{W}_{32} & \boldsymbol{W}_{33} \end{bmatrix} \end{array} \tag{8}$$

where $\boldsymbol{W}_{21}$ is a matrix that represents the weights of cluster 2 with respect to cluster 1, matrix $\boldsymbol{W}_{32}$ represents the weights of cluster 3 with respect to cluster 2, and matrix $\boldsymbol{W}_{13}$ shows the weights of cluster 1 with respect to cluster 3. In addition, matrix $\boldsymbol{W}_{33}$ is denoted as the inner dependence and feedback within cluster 3. The weighted supermatrix is derived by setting the "all columns sum" to unity by normalization. This step is very similar to the concept of the Markov chain for ensuring that the sum of the probabilities of all states equals 1 (Huang et al., 2005). Then, the weighted supermatrix can be raised to limiting powers, as in Eq. (9), to calculate the overall priorities of weights.

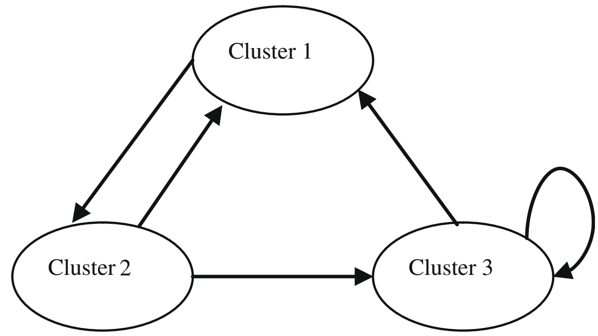


**Fig. 2.** Illustration of system structure.

$$\lim_{k\to\infty} W^k \tag{9}$$

## 4. An empirical case: Case of the Pei-Keng brook environment watershed plan systems

Located in Taiwan, the study area comprises four parts. This planning includes the Guoxing town of Nantou County, where the township's Nangang River has a small stream and the Pei-Keng creek rises in the Sijiao mountain (1172M), the Cukeng branch rises in the Kandou mountain (1097M), the Juicaihu creek rises in the Juifener mountain (1174M), and the Hongxianshui branch rises in the Heshangtou mountain (955M) (Fig. 3).

The plan systems are complex, composed of environmental, software, hardware, and human factors, and it is clear that environment watershed plan measures must be context-dependent and based on real operations. Three senior watershed experts were consulted, and the *Operation Inspection Handbook* of the Soil and Water Conservation Bureau, Council of Agriculture, and Executive Yuan (SWCB) were consulted to develop a three-dimensional plan system (Watershed Management and Erosion Control, Ecological Restoration, and Environmental Construction) with each dimension having six to eight criteria. A questionnaire was given to three groups comprising 15 experts – five from the university of expert scholars (including Water Resources Engineering and Conservation, Landscape and Recreation, Urban Planning, Environment Engineering, and Architectural Engineering), five from government departments, and five from industry – ranking each criterion with respect to sustainable development using a 5-point scale ranging from 4 (extremely important) to 0 (no effect). The highest scoring three criteria from each dimension were extracted to construct the system for measuring the environment watershed plan. Since comprehensive conservation in environment watershed plan system rates is an important factor in plan measurements, it is used as a further criterion (Table 1).

### 4.1. Problem descriptions of the watershed in research areas

The Pei-Keng brook catchments geographical position is situated in the Guoxing town region of Nantou County, Taiwan (23°5315N–23°5836N, 120°4915E–120°5301E), as shown with the aid of the geographical information system (GIS), and covers about 3810.21 ha, accounting for 46% of the total land area of the towns (Fig. 3). Within the boundaries, mountain winds present a north and south long and narrow tendency, the brook flows from south to north, the highest mountain peak is about 1200 m in elevation, the lowest river valley elevation is about 300 m, and the average elevation is 686.96 m (Fig. 4). The entire district third-level

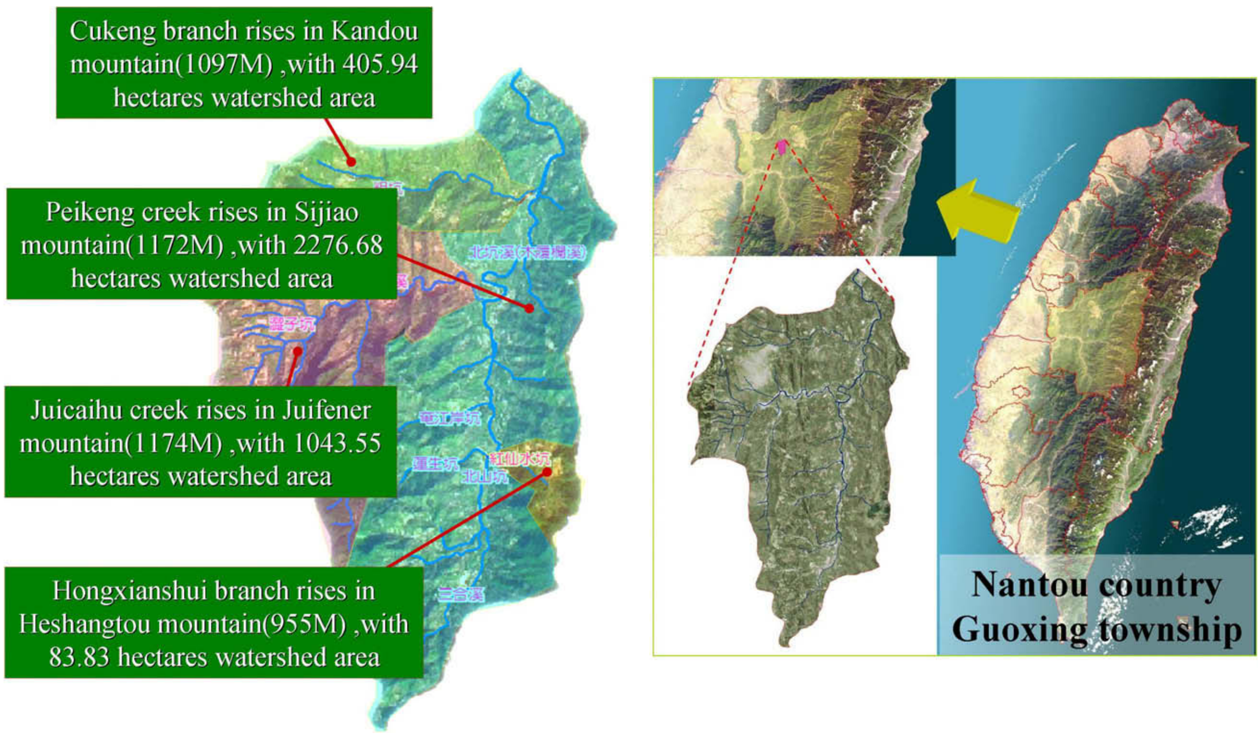


**Fig. 3.** Regional map of the Pei-Keng brook of catchment area.

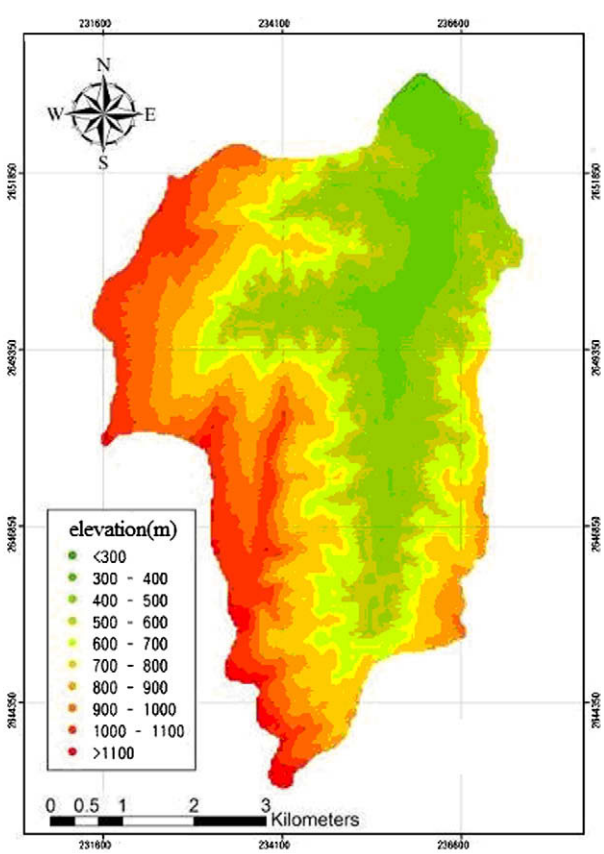


**Fig. 4.** High Cheng's distribution map of the Pei-Keng brook of catchment area.

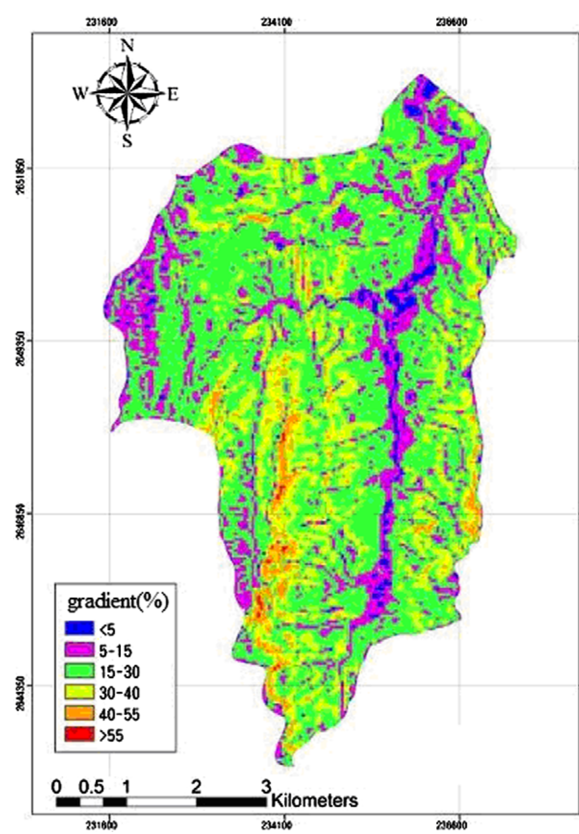


**Fig. 5.** Distribution map of the slope of the Pei-Keng brook of catchment area.

slope reaches 56.83%, and above the third-level slope accounts for 77.95% (Fig. 5). The slope accounts are many of easts for 22.14% (Fig. 6). Gather and fall is located in gorges in the main countryside, surrounded by mountains on four sides. The average width in the water district is about 4.5 km, the length is about 9 km on average, and, for the plan, the major length in the area is about 11.2 km,

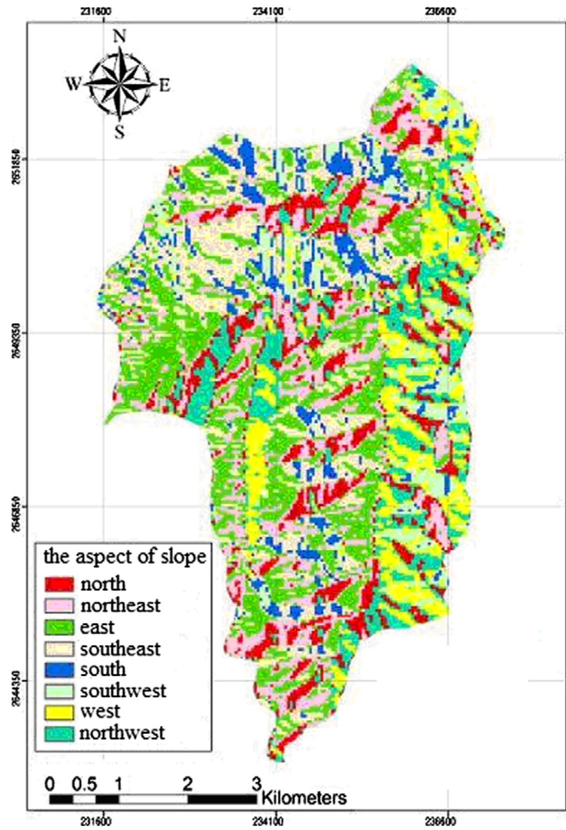


**Fig. 6.** The slope is to the distribution map of the Pei-Keng brook of catchment area.

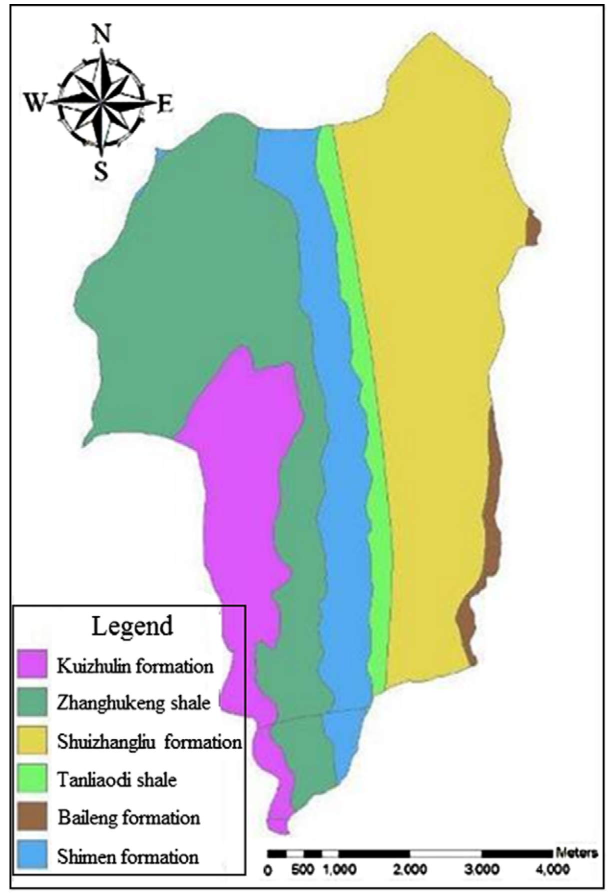


**Fig. 7.** Stratum distribution map of the Pei-Keng brook of catchment area.

about 1/11 that the average slope is lowered. The 'Kuichulin formation' and 'Changhukeng shale' take the heaviest proportions, 35.52% and 31.67% stratum, respectively (Fig. 7). The geological structure of Israel, 'the Sandstone and Shale correlation, coal formation, including the coal seam', is 57.49% (Fig. 8) in order to mainly have 'large cogongrass Pu – a winter, fault of the hole in water' with the main fault. The soil makes up and relies mainly on the fact that 'Colluvial soils' accounts for 39.95% (Fig. 9).

### 4.2. Measuring relationships among dimensions for building NRM

The aim is not only to determine the most important plan criteria, but also to measure relationships among criteria for building a NRM (network relation map). A questionnaire was given to three groups comprising 15 experts – five from the universities of the expert scholars (including Water Resources Engineering and Conservation, Landscape and Recreation, Urban Planning, Environment Engineering, and Architectural Engineering), five from governmental departments, and five from industry – ranking each criterion with respect to sustainable development using a 5-point scale ranging from 5 (extremely important) to 1 (no effect). The highest scoring three criteria from each dimension were extracted to construct the system for measuring the environment watershed plan. Since comprehensive conservation in environment watershed plan system rates is an important factor in plan measurements, it is used as a further criterion. The aim is not only to determine the most important plan criteria, but also to measure relationships among criteria. The watershed experts were thus asked to determine the importance of the relationships among the dimensions. The average initial direct-relation $4 \times 4$ matrix A, obtained by pair-wise comparisons in terms of influences and directions between dimensions, is shown in (Table 2).

As matrix $\boldsymbol{A}$ shows, the normalized direct-relation $\boldsymbol{D}$ is calculated from Eqs. (1) and (2). Next, using Eq. (3), the total-influence $\boldsymbol{T}$ can be derived as shown in Table 3. Then, by using Eqs. (5) and (6), the sum of total-influence given and received by each dimension can be derived as shown in Table 4.

Based on this, the IRM of the DEMATEL method can be obtained and shown in Fig. 10 by using Table 3 and Fig. 11 by using Table 4.

### 4.3. Weighting of criteria in environment watershed plan systems

After determining the relationship structures among environment watershed plan system factors, the ANP method is applied to obtain criteria weights. Initially, the importance of relationships between each criterion was compared based on the IRM. For example, the experts were asked to respond to a series of questions, such as "For the environment watershed plan and sustainable development, how much more important is one operation criteria over another?" These pair-wise comparisons are based on the AHP concept, and the plan was graded on a 9-point scale with a score of 1 indicating equal importance and 9 indicating extreme importance of one element over another. As the local weights of these criteria are obtained through the principal eigenvector of comparison, an unweighted supermatrix can be generated (Table 5). We normalized the unweighted supermatrix based on the total-influence matrix (see Table 3, influence normalized matrix in figures of parentheses) shown in (Table 6).

The environment watershed plan program is complex, including soil and water conservation, environmental ecology, environmental construction, and sustainable development, etc. Thus, we developed a novel method that combines the DEMATEL total-influence matrix and unweighted supermatrix in ANP. First, we

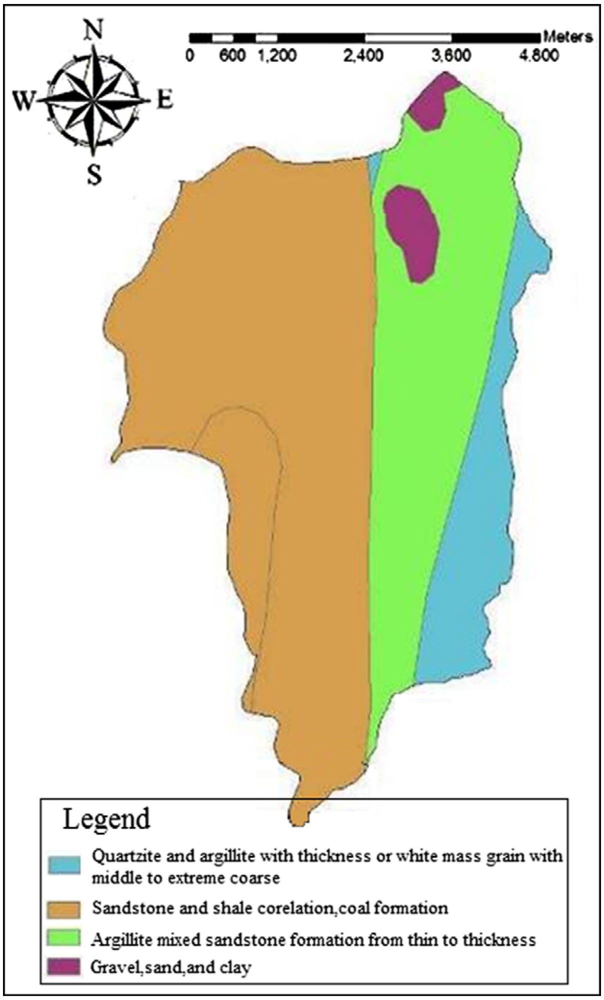


**Fig. 8.** Geological distribution map of the Pei-Keng brook of catchment area.

calculated the total-influence in the normalized matrix T, obtained each dimension weight and then the * unweighted supermatrix. The research for the novel hybrid MCDM model can be derived from feedback regarding the dimensions and each criteria relationship. Finally, the outcome is shown in Table 7.

Based on Table 6, the normalization weighted supermatrix power limit $k \to \infty$ can be obtained as shown in Table 7.

By calculating the limiting power of the weighted supermatrix, $\lim_{k\to\infty} \boldsymbol{W}^k$, Eq. (9) is applied by ANP until a steady-state condition is reached (Table 8). Each row represents the weight of each criterion. As seen in the table, the highest priority is the Prevention of development rate (12.0%), while the lowest priority is the Tour facilities (3.3%). For Environmental conservation and Artificial disturbance minimization, Prevention of development is assessed at 10.8% and 12.0%. For Watershed Management and Erosion Control criteria, such priorities include violent perturbations of landslides, potential debris flow torrents, problems of channel silt, and soil and water conservation of roads. For Environmental Construction criteria, such priorities include ecological potentiality and restriction, resources of humane industries, potentiality of land development, peripheral landscapes and natural features, and tour facilities. The Environmental Conservation was determined to be the most important criterion within Prevention of development (see Fig. 11).

### 4.4. Using the method to evaluate environment watershed plan levels

Thirteen senior environment watershed plan administrators, employed by Taiwan's Soil and Water Conservation Bureau, Council of Agriculture, and Executive Yuan, conducted plan assessments and participated in the annual plan evaluation program for the Pei-Keng brook watershed in Taiwan. For the watershed, these administrators were asked to evaluate the level of satisfaction for each criterion, excluding ecological restoration rates and ratios of certified technicians; these were directly obtained from the Taiwan Soil and Water Conservation Bureau, Council of Agriculture, and Executive statistics report. The normalized performance score [0, 1] for the environment watershed is shown in Table 9. By way of performance values and relative results, the AHP is independent and the ANP is feedback. They cause different effects. We can compare and see the global weight in AHP and ANP. For AHP, each criterion that is globally weighted is not conspicuous. However, for ANP, it is conspicuous. For the environment watershed plan, the aspired gap is the prevention of development and environmental conservation, which is the same as the DEMATEL of the impact-direction map shown in Fig. 11. Integration of the performance indexes scores of the Pei-Keng brook watershed in AHP and ANP shows that environmental conservation is scored at 5.42 at the lowest. At first, it must improve and provide tactics. Furthermore, there are watershed management and erosion control, environmental construction, and ecological restoration. Thus, we can conclude that the Pei-Keng brook watershed is the most abundant natural resource.

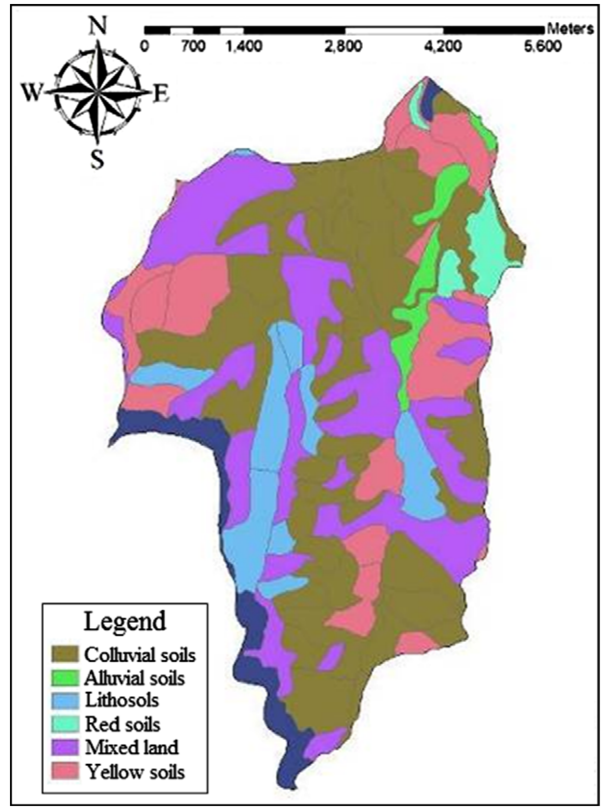


**Fig. 9.** Soil distribution map of the Pei-Keng brook of catchment area.

Once we achieved the desired levels (10 scores), the scores were as follows: Environmental Conservation is 4.58, Watershed Management and Erosion Control is 4.35, Environmental Construction is 3.67, and Ecological Restoration is 3.54. The results of the implication of better management and improved program are based on Fig. 11.

### 4.5. Discussion

Via Table 5 (the sum of influences given and received for dimensions) values, we then draw the impact-direction map shown in Fig. 11. It shows that "$D_4$ Environmental Conservation" is more

**Table 2**
The initial influence matrix *A*.

| Dimensions | Watershed management and erosion control ($D_1$) | Ecological restoration ($D_2$) | Environmental construction ($D_3$) | Environmental conservation ($D_4$) |
|---|---|---|---|---|
| Watershed management and erosion control ($D_1$) | 0 | 2.0 | 2.4 | 2.4 |
| Ecological restoration ($D_2$) | 3.2 | 0 | 2.2 | 2.2 |
| Environmental construction ($D_3$) | 3.6 | 3.0 | 0 | 2.0 |
| Environmental conservation ($D_4$) | 3.6 | 3.8 | 2.8 | 0 |

**Table 3**
The total-influence matrix *T*.

| Dimensions | Watershed management and erosion control ($D_1$) | Ecological restoration ($D_2$) | Environmental construction ($D_3$) | Environmental conservation ($D_4$) | Total-influence normalized |
|---|---|---|---|---|---|
| Watershed management and erosion control ($D_1$) | 0.793 ($w_{D_1D_1} = 0.25$) | 0.846 ($w_{D_1D_2} = 0.27$) | 0.793 ($w_{D_1D_3} = 0.25$) | 0.745 ($w_{D_1D_4} = 0.23$) | – (1.00) |
| Ecological restoration ($D_2$) | 1.087 ($w_{D_2D_1} = 0.32$) | 0.731 ($w_{D_2D_2} = 0.21$) | 0.826 ($w_{D_2D_3} = 0.24$) | 0.776 ($w_{D_2D_4} = 0.23$) | – (1.00) |
| Environmental construction ($D_3$) | 1.192 ($w_{D_3D_1} = 0.3$) | 1.023 ($w_{D_3D_2} = 0.26$) | 0.712 ($w_{D_3D_3} = 0.18$) | 0.821 ($w_{D_3D_4} = 0.26$) | – (1.00) |
| Environmental conservation ($D_4$) | 1.339 ($w_{D_4D_1} = 0.31$) | 1.201 ($w_{D_4D_2} = 0.28$) | 1.037 ($w_{D_4D_3} = 0.24$) | 0.762 ($w_{D_4D_4} = 0.18$) | – (1.00) |

**Table 4**
The sum of influences given and received on dimensions.

| Dimensions | $r_i$ | $c_i$ | $r_i + c_i$ | $r_i - c_i$ |
|---|---|---|---|---|
| Watershed management and erosion control ($D_1$) | 3.177 | 4.410 | **7.587** | −**1.232** |
| Ecological restoration ($D_2$) | 3.419 | 3.800 | **7.219** | −**0.381** |
| Environmental construction ($D_3$) | 3.747 | 3.369 | **7.116** | **0.379** |
| Environmental conservation ($D_4$) | 4.339 | 3.104 | **7.443** | **1.235** |

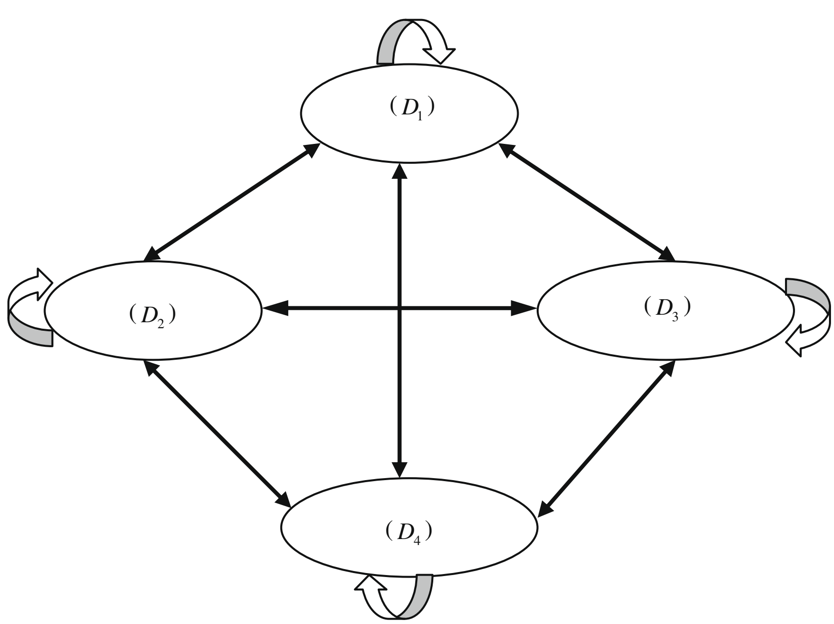


**Fig. 10.** The impact-relations-map of relations within safety.

important than the other three. Thus, we can sequence $D_4 \succ D_3 \succ D_2 \succ D_1$.

According to ANP, we designed and obtained Table 7 in order to calculate the weighted and the unweighted supermatrix based on the total influence normalized matrix. Table 8 shows the environment watershed plan weighted supermatrix indexes. Each row represents the weight of each criterion. As seen in the table, the highest priority is the Prevention of development rate (12.00%), while the lowest priority is Tour facilities (3.3%). For Environmental Conservation, artificial disturbance minimization and Prevention of development are assessed at 10.8% and 12.0%. For Watershed Management and Erosion Control criteria, the priorities

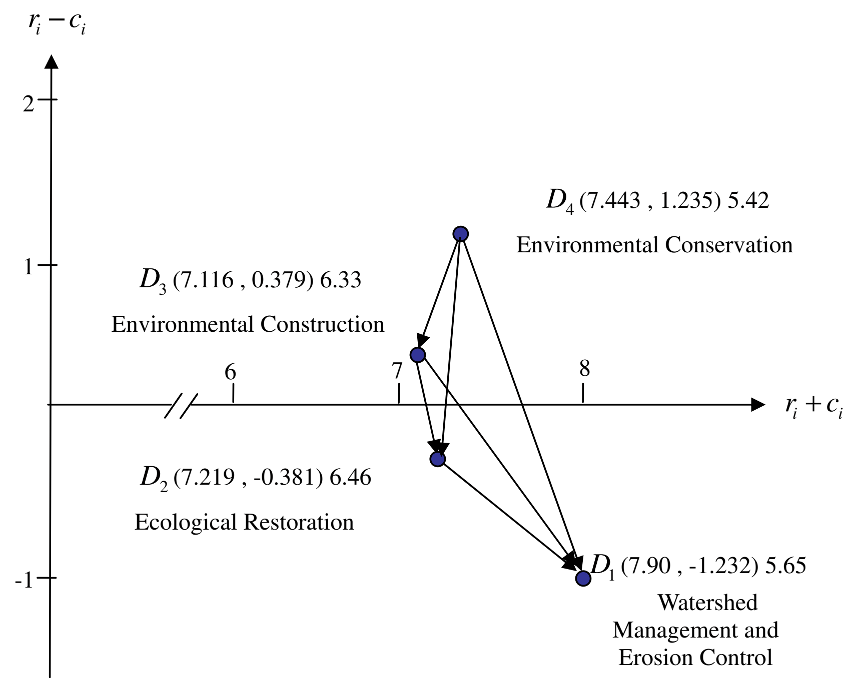


**Fig. 11.** The impact-direction map.

**Table 5**
The unweighted supermatrix.

| | $D_1$ | | | | $D_2$ | | | | $D_3$ | | | | | $D_4$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ |
| $C_1$ | 1 | 0 | 0 | 0 | 0.31 | 0.25 | 0.24 | 0.29 | 0.31 | 0.32 | 0.33 | 0.24 | 0.37 | 0.32 | 0.34 |
| $C_2$ | 0 | 1 | 0 | 0 | 0.27 | 0.21 | 0.27 | 0.22 | 0.20 | 0.23 | 0.26 | 0.26 | 0.28 | 0.29 | 0.32 |
| $C_3$ | 0 | 0 | 1 | 0 | 0.24 | 0.25 | 0.24 | 0.25 | 0.31 | 0.26 | 0.22 | 0.26 | 0.21 | 0.21 | 0.23 |
| $C_4$ | 0 | 0 | 0 | 1 | 0.19 | 0.29 | 0.24 | 0.24 | 0.17 | 0.19 | 0.20 | 0.24 | 0.14 | 0.18 | 0.11 |
| $C_5$ | 0.20 | 0.2 | 0.26 | 0.30 | 1 | 0 | 0 | 0 | 0.30 | 0.23 | 0.31 | 0.28 | 0.33 | 0.28 | 0.35 |
| $C_6$ | 0.33 | 0.3 | 0.28 | 0.23 | 0 | 1 | 0 | 0 | 0.30 | 0.28 | 0.28 | 0.23 | 0.24 | 0.28 | 0.23 |
| $C_7$ | 0.24 | 0.2 | 0.24 | 0.27 | 0 | 0 | 1 | 0 | 0.23 | 0.33 | 0.25 | 0.20 | 0.24 | 0.31 | 0.27 |
| $C_8$ | 0.23 | 0.3 | 0.22 | 0.20 | 0 | 0 | 0 | 1 | 0.18 | 0.16 | 0.16 | 0.30 | 0.19 | 0.14 | 0.15 |
| $C_9$ | 0.29 | 0.30 | 0.28 | 0.27 | 0.31 | 0.34 | 0.49 | 0.25 | 1 | 0 | 0 | 0 | 0 | 0.18 | 0.30 |
| $C_{10}$ | 0.24 | 0.25 | 0.17 | 0.20 | 0.14 | 0.16 | 0.11 | 0.15 | 0 | 1 | 0 | 0 | 0 | 0.15 | 0.22 |
| $C_{11}$ | 0.12 | 0.15 | 0.15 | 0.16 | 0.14 | 0.16 | 0.11 | 0.13 | 0 | 0 | 1 | 0 | 0 | 0.12 | 0.11 |
| $C_{12}$ | 0.14 | 0.20 | 0.19 | 0.19 | 0.19 | 0.20 | 0.16 | 0.23 | 0 | 0 | 0 | 1 | 0 | 0.30 | 0.22 |
| $C_{13}$ | 0.21 | 0.10 | 0.21 | 0.18 | 0.21 | 0.14 | 0.14 | 0.25 | 0 | 0 | 0 | 0 | 1 | 0.24 | 0.15 |
| $C_{14}$ | 0.53 | 0.54 | 0.47 | 0.58 | 0.45 | 0.54 | 0.46 | 0.30 | 0.45 | 0.54 | 0.45 | 0.46 | 0.30 | 1 | 0 |
| $C_{15}$ | 0.47 | 0.46 | 0.53 | 0.42 | 0.55 | 0.46 | 0.54 | 0.70 | 0.55 | 0.46 | 0.55 | 0.54 | 0.70 | 0 | 1 |

**Table 6**
Weighting the unweighted supermatrix based on total-influence normalized matrix.

| Dimensions | Watershed management and erosion control ($D_1$) | Ecological restoration ($D_2$) | Environmental construction ($D_3$) | Environmental conservation ($D_4$) |
|---|---|---|---|---|
| Watershed management and erosion control ($D_1$) | $w_{D_1D_1}\mathbf{W}_{D_1D_1}$ | $w_{D_2D_1}\mathbf{W}_{D_2D_1}$ | $w_{D_3D_1}\mathbf{W}_{D_3D_1}$ | $w_{D_4D_1}\mathbf{W}_{D_4D_1}$ |
| Ecological restoration ($D_2$) | $w_{D_1D_2}\mathbf{W}_{D_1D_2}$ | $w_{D_2D_2}\mathbf{W}_{D_2D_2}$ | $w_{D_3D_2}\mathbf{W}_{D_3D_2}$ | $w_{D_4D_2}\mathbf{W}_{D_4D_2}$ |
| Environmental construction ($D_3$) | $w_{D_1D_3}\mathbf{W}_{D_1D_3}$ | $w_{D_2D_3}\mathbf{W}_{D_2D_3}$ | $w_{D_3D_3}\mathbf{W}_{D_3D_3}$ | $w_{D_4D_3}\mathbf{W}_{D_4D_3}$ |
| Environmental conservation ($D_4$) | $w_{D_1D_4}\mathbf{W}_{D_1D_4}$ | $w_{D_2D_4}\mathbf{W}_{D_2D_4}$ | $w_{D_3D_4}\mathbf{W}_{D_3D_4}$ | $w_{D_4D_4}\mathbf{W}_{D_4D_4}$ |

include violent perturbations of landslides, potential debris flow torrents, problems of channel silt, and soil and water conservation of roads. For the Environmental Construction criteria, the priorities are ecological potentiality and restriction, resources of humane industries, potentiality of land development, peripheral landscapes and natural features, and Tour facilities. The Environmental Conservation was determined to be the most important criterion within the Prevention of development (see Fig. 11).

From the results given earlier, using the DEMATEL in conjunction with an ANP, we can determine the relative weights of the criteria. The DEMATEL works in an ANP to construct a new measurement model for environment watershed plan effects. For

**Table 7**
Weighting the unweighted supermatrix based on total-influence normalized matrix.

| | *D1* | | | | *D2* | | | | *D3* | | | | | *D4* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ |
| $C_1$ | 0.250 | 0.000 | 0.000 | 0.000 | 0.099 | 0.080 | 0.077 | 0.093 | 0.093 | 0.096 | 0.099 | 0.072 | 0.111 | 0.099 | 0.105 |
| $C_2$ | 0.000 | 0.250 | 0.000 | 0.000 | 0.086 | 0.067 | 0.086 | 0.070 | 0.060 | 0.069 | 0.078 | 0.078 | 0.084 | 0.090 | 0.099 |
| $C_3$ | 0.000 | 0.000 | 0.250 | 0.000 | 0.077 | 0.080 | 0.077 | 0.080 | 0.093 | 0.078 | 0.066 | 0.078 | 0.063 | 0.065 | 0.071 |
| $C_4$ | 0.000 | 0.000 | 0.000 | 0.250 | 0.061 | 0.093 | 0.077 | 0.077 | 0.051 | 0.057 | 0.060 | 0.072 | 0.042 | 0.056 | 0.034 |
| $C_5$ | 0.054 | 0.054 | 0.070 | 0.081 | 0.210 | 0.000 | 0.000 | 0.000 | 0.078 | 0.060 | 0.081 | 0.073 | 0.086 | 0.078 | 0.098 |
| $C_6$ | 0.089 | 0.081 | 0.076 | 0.062 | 0.000 | 0.210 | 0.000 | 0.000 | 0.078 | 0.073 | 0.073 | 0.060 | 0.062 | 0.078 | 0.064 |
| $C_7$ | 0.065 | 0.054 | 0.065 | 0.073 | 0.000 | 0.000 | 0.210 | 0.000 | 0.060 | 0.086 | 0.065 | 0.052 | 0.062 | 0.087 | 0.076 |
| $C_8$ | 0.062 | 0.081 | 0.059 | 0.054 | 0.000 | 0.000 | 0.000 | 0.210 | 0.047 | 0.042 | 0.042 | 0.078 | 0.049 | 0.039 | 0.042 |
| $eC_9$ | 0.073 | 0.075 | 0.070 | 0.068 | 0.074 | 0.082 | 0.118 | 0.060 | 0.180 | 0.000 | 0.000 | 0.000 | 0.000 | 0.047 | 0.078 |
| $C_{10}$ | 0.060 | 0.063 | 0.043 | 0.050 | 0.034 | 0.038 | 0.026 | 0.036 | 0.000 | 0.180 | 0.000 | 0.000 | 0.000 | 0.039 | 0.057 |
| $C_{11}$ | 0.030 | 0.038 | 0.038 | 0.040 | 0.034 | 0.038 | 0.026 | 0.031 | 0.000 | 0.000 | 0.180 | 0.000 | 0.000 | 0.031 | 0.029 |
| $C_{12}$ | 0.035 | 0.050 | 0.048 | 0.048 | 0.046 | 0.048 | 0.038 | 0.055 | 0.000 | 0.000 | 0.000 | 0.180 | 0.000 | 0.078 | 0.057 |
| $C_{13}$ | 0.053 | 0.025 | 0.053 | 0.045 | 0.050 | 0.034 | 0.034 | 0.060 | 0.000 | 0.000 | 0.000 | 0.000 | 0.180 | 0.062 | 0.039 |
| $C_{14}$ | 0.12 | 0.12 | 0.11 | 0.13 | 0.10 | 0.12 | 0.11 | 0.07 | 0.12 | 0.14 | 0.12 | 0.12 | 0.08 | 0.18 | 0.00 |
| $C_{15}$ | 0.11 | 0.11 | 0.12 | 0.10 | 0.13 | 0.11 | 0.12 | 0.16 | 0.14 | 0.12 | 0.14 | 0.14 | 0.18 | 0.00 | 0.18 |

**Table 8**
The stable matrix of ANP when power limit $k \to \infty$ (ANP).

| | $D_1$ | | | | $D_2$ | | | | $D_3$ | | | | | $D_4$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ |
| $\mathbf{C_1}$ | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 | 0.086 |
| $\mathbf{C_2}$ | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 | 0.073 |
| $\mathbf{C_3}$ | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 |
| $\mathbf{C_4}$ | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 | 0.056 |
| $\mathbf{C_5}$ | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 |
| $\mathbf{C_6}$ | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 |
| $\mathbf{C_7}$ | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 |
| $\mathbf{C_8}$ | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 | 0.052 |
| $\mathbf{C_9}$ | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 |
| $\mathbf{C_{10}}$ | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 |
| $\mathbf{C_{11}}$ | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 |
| $\mathbf{C_{12}}$ | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 | 0.051 |
| $\mathbf{C_{13}}$ | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 | 0.044 |
| $\mathbf{C_{14}}$ | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 | 0.108 |
| $\mathbf{C_{15}}$ | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 | 0.120 |

**Table 9**
Performance values and relative importance of criteria by AHP and ANP.

| Dimensions/criteria | Performance | AHP | | ANP | |
|---|---|---|---|---|---|
| | | Local weight | Global weight | Local weight | Global weight |
| *Watershed management and erosion control* ($D_1$) | | *0.266* | | *0.283* | |
| Violent perturbation of landslide ($C_1$) | 5.0 | 0.235 | 0.062 | 0.294 | 0.086 |
| Potential debris flow torrent ($C_2$) | 6.9 | 0.275 | 0.073 | 0.265 | 0.073 |
| River of erosion and deposition ($C_3$) | 5.0 | 0.238 | 0.063 | 0.235 | 0.069 |
| Soil and water conservation of roads ($C_4$) | 5.8 | 0.252 | 0.067 | 0.206 | 0.056 |
| *Ecological restoration*($D_2$) | | *0.283* | | *0.249* | |
| Activities of biological community ($C_5$) | 6.9 | 0.233 | 0.066 | 0.251 | 0.068 |
| Habitat mold and regeneration ($C_6$) | 5.7 | 0.258 | 0.073 | 0.273 | 0.068 |
| Integrality of ecological corridor ($C_7$) | 6.3 | 0.261 | 0.074 | 0.239 | 0.061 |
| Ecological monitoring and management ($C_8$) | 5.5 | 0.248 | 0.070 | 0.237 | 0.052 |
| *Environmental construction* ($D_3$) | | *0.314* | | *0.240* | |
| Ecological potentiality and restriction ($C_9$) | 6.2 | 0.216 | 0.068 | 0.279 | 0.069 |
| Peripheral landscape and natural features ($C_{10}$) | 6.0 | 0.213 | 0.067 | 0.164 | 0.044 |
| Tour facilities ($C_{11}$) | 7.0 | 0.207 | 0.065 | 0.153 | 0.033 |
| Resources of humane industry ($C_{12}$) | 7.0 | 0.168 | 0.053 | 0.230 | 0.051 |
| Potentiality of land development ($C_{13}$) | 5.6 | 0.196 | 0.062 | 0.175 | 0.044 |
| *Environmental conservation* ($D_4$) | | *0.137* | | *0.228* | |
| Artificial disturbance minimizing ($C_{14}$) | 5.1 | 0.474 | 0.065 | 0.395 | 0.108 |
| Forbid developing ($C_{15}$) | 5.7 | 0.526 | 0.072 | 0.605 | 0.120 |

future study, we make the following recommendations that may be worthy of further research. We can design and plan the environment watershed and use "VIKOR" or "PROMETHEE" for the environment watershed plan strategy.

**Table 10**
Integrating performance indexes scores of Pei-Keng brook watershed.

| Dimensions | Using AHP | Using ANP |
|---|---|---|
| Watershed management and erosion control ($D_1$) | 5.72 | 5.65 |
| Ecological restoration ($D_2$) | 6.40 | 6.46 |
| Environmental construction ($D_3$) | 6.34 | 6.33 |
| Environmental conservation ($D_4$) | 5.42 | 5.42 |
| Total average | 5.97 | 5.96 |

**Table 11**
Environment watershed plan strategy.

| Formula | Strategy |
|---|---|
| P1 | Control sand production, clear silt, and dredging, prevent soil barrier lakes that sand blocks form, increase river drain-off water, and the source of water conservation ability |
| P2 | Set up the integrity of the ecological corridor, improve the diversified cache environment, and monitor the quantity of development of the ecological species |
| P3 | Engage in ecology and land utilization to investigate, channel writing style dose and industry's characteristics into locals, in order to be regarded and planned as the natural and harmonious aesthetic feeling of the environment |
| P4 | Delimit the ecological sensitizing range and protection zone, reduce artificial disturbance, and allow the ecology to reach its natural equilibrium |

The proposed model is well suited to deal with any environment watershed plan strategy problems with a complicated strategy. Because the ANP criteria are interdependent, they can be applied to many fields such as wetland planning, psychology, consumer behavior, human resources management (see Table 10).

The environment watershed plan strategy is shown in Table 11. It can reduce environment calamity and emphasize the goal of a sustainable environment.

## 5. Conclusions and remarks

Using the DEMATEL in conjunction with an ANP, we determined the relative weights of the criteria. The DEMATEL works in an ANP to construct a new measurement model for environment watershed effects, which may be worthy of further research. This is an important finding in this study. The proposed model is suitable to deal with any decision problems that are complicated and confusing and whose criteria are interdependent. This model can be applied to many fields such as environment planning, psychology, consumer behavior, human resources management. The study establishes a causal model of the environment watershed plan effect, and the relational structure model is verified through satisfactory statistical techniques in order to confirm the model efficiency. The study finds, in the environment watershed plan, that A outranks B. Then, the environment watershed plan ranking indicates the criterion that has the best plan record, Environmental Conservation $\succ$ Environmental Construction $\succ$ Ecological Restoration $\succ$ Watershed Management and Erosion Control. The proposed model uses DEMATEL to find out influence factors and applies ANP to determine which criteria/factor is more important and will influence the efficiency of the environment watershed plan effect. The DEMATEL technique compares pairs of mutual relationships to the survey materials and clarifies the essence of the problem, so we can determine the crux of the problem based on the novel hybrid MCDM model method, which may help to make strategic plans. In the past, poor watershed plan records have led Taiwan's Soil and Water Conservation Bureau and Council of Agriculture to conduct annual plan evaluations of the Pei-Keng brook watershed. Traditionally, the plan is based on the number of storm water catastrophes and possibly "land and monitored" rates during audits. These statistics are not always helpful when catastrophe incidents or land and monitored rates are very low and give little indication of possible future trends. Based on several aspects of environment watershed plan systems, we have combined the DEMATEL and ANP methods to form a hybrid MCDM approach that considers interdependence among a range of criteria and their weighting. An empirical testing of the approach using a Taiwanese case study illustrates the usefulness of our model.

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