Environment Planning of Watershed Area by Using a Hybrid MCDM Model

Yen Lee, Ho-Shong Hou, Yi-Chen Chen, and Gwo-Hsiung Tseng

Abstract— *In the real word, environment-watershed Area sustainable development is an important issue for human life comfortable. Its sustainable development is affected by natural disasters such as earthquake, typhoon, torrential rain, etc. The decision making process are uncertain in a number of ways, such as subjective perception, natural language, etc. Most dimensions/factors have interdependent and interactive features, so they cannot be evaluated by conventional measures method. Multiple Criteria Decision Making (MCDM) model is used for addressing dependent relationships among the criteria. MCDM model is applied to measure and evaluate watershed environmental problems successfully in this paper.*

***Keywords*— Watershed, Wetland, Multiple Criteria Decision Making, MCDM.**

1. INTRODUCTION

Research Background and Purpose

The birthplace of the upstream terrain steep is uninhabitable. However, the watershed area from the beginning of the middle reaches till the lower reaches of the river to the Coastal of wetland are more gentle, which is a more complete regional environment for inhabitation. It is very important to manage the regional environment since it affects human life, and natural, ecological, and environmental sustainable development. In the recent years, the overall environmental impact of natural disasters (such as earthquakes, typhoons, and rainstorms) as well as a large number of man-made disasters for economic gains, and the rapid development of land under the living areas have caused serious environmental impact and damage, and have created an imbalance of regional space in the natural ecosystem.

The main objective of regional environmental planning for sustainable development is to improve the gaps of criteria for achieving the aspired levels of human welfare, while taking into account the factors of comfort and safety. There are some critical components in the environmental project that need to considered for evaluating the strategy with the decision making process. In general, these critical components are numerous in number and are known to affect each other, and therefore, the analysis is complex.

A sustainable environment is a function of two major components, ecology and humans, that is, sustainable decision-making should have two simultaneous goals: (1) Achievement of human development to secure high standards of living; (2) Protection and improvement of the environment now and for the future generations.

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Research Issues and Objectives

The entire process of planning depends upon how the planners or policymakers understand and interpret the concept of environmental sustainable development and regional environment planning on the nature of the planning mechanism prevalent in a country. Hence, the present study aims at developing a hybrid novel model for strategy evaluation, alternative selection, and the regional environmental project optimization. Finally, an empirical regional environment problem is investigated in order to demonstrate a novel hybrid MCDM (Multiple Criteria Decision Making) model proposed for future applications. The results indicate that the proposed method is suitable for the real world.

Framwork Research Methods

In the first stage for the evaluation of environmental watershed region issues using multiple criteria decision making methods, the best project selection for the regional environment planning of evaluated criteria, the aspects under consideration, and the feasible alternatives are defined through brainstorming, scenario writing, and discussion with experts.

In the second stage, statistical factor analysis is employed in order to extract some common factors for identifying the relationship among these evaluated criteria. The other approaches available for identifying the relationship among criteria include DEMATEL (Decision-making trial and evaluation laboratory), and ANP based on the DEMATEL technique to build the network relationship map (NRM) for constructing Super matrix.

In the third stage, the weights of evaluated criteria are assessed based on the fuzzy hierarchical analytic process by utilizing geomeans to integrate the group judgment. In the fourth stage, the performance score of feasible alternatives corresponding to criteria is calculated, and fuzzy AHP (Analytic hierarchical process) is employed to derive the synthetic values within each common factor.

Finally, the preferred order is determined for all alternatives according to the final synthetic value. Furthermore, an introduction to De Novo Programming is presented for solving the optimized distribution network design in the environment of watershed region.

2. CONCEPT OF REGIONAL ENVIRONMENT PLAN MEASUREMENTS

Environment-Watershed Plan Measurements

Environment watershed plan measurements involve a number of complex factors, however, including management engineering, ecological restoration, environmental construction, and environmental conservation issues.

Many factors/criteria; the environmental watershed plan index are considered to focus on catastrophe, human safety, comfort, interest, the ecological system, and environmental sustainability. 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. 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.

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. 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 have been studied.

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 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 have been statistically described from natural disasters and the artificial merging of two levels. Firstly, typhoons, torrential rains, and earthquakes cause the rivers to overflow, cause the violent landslides, and result in potential debris flow. In addition, environmental demand for space and water has increased artificial disturbances changes of land pattern utilization and terrain features carry out the transition of development.

How to solve the environmental watershed problems? Firstly, from the watershed environment survey data, some characteristic values that improve and stabilize the river canal shape, increase the activities of the biological community are found. There are 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.

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 non-projects 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.

The Best Plan Environment-Watershed Measurement

For the best plan or government authorities, plan engineering not only acquires nice planning and design but also good plan so as to achieve the three goals for planning management with high efficiency and high quality.

The analytic hierarchy process (AHP) method is widely used for multiple attribute decision-making (MADM) and has successfully been applied to many practical decision-making problems. The empirical effectiveness and theoretical validity of the AHP have also been discussed by previous study and this discussion has focused on four main areas.

Via expert questionnaire suggest some factors/criteria of Environment-watershed can join with the same attribute. Thus in the first dimensions of watershed management and erosion control, we join: (1) violent landslide perturbations, to (2) potential debris flow torrents; in the second dimensions of ecological restoration, to join (5) activities of biological

communities, to (6) habitat molds and regeneration; in the third dimensions of environmental construction, to address (7) Landscape tour and natural features, (8) Human industry and resource of land, to take the place of (9) ecological potentiality and restriction, (10) peripheral landscapes and natural features, (11) tour facilities, (12) resources of humane industries, (13) potentiality of land development. In summary, it needs to consider factors / criteria which have to enclose four dimensions and ten factors/criteria, i.e. including: (1) watershed management and erosion control; (2) ecological restoration; (3) environmental construction; (4) environmental conservation. Based on these, 10 evaluation criteria for the hierarchical structure were to use in our study.

The hierarchical structure adopted in this study to deal with the problems of plan assessment for environment-watershed as shown in Figure 1.

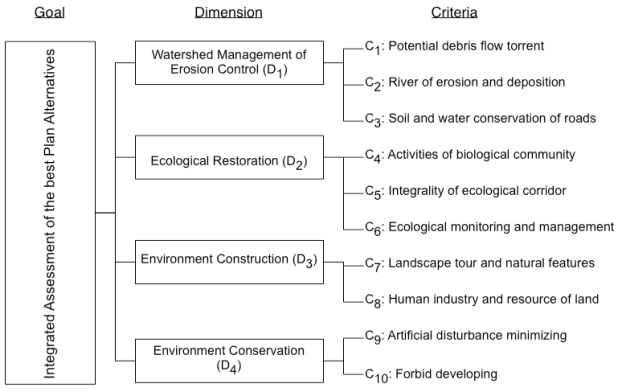

Fig.1. The Hierarchical Structure for the Best Plan Alternatives Assessment.

Wetlands Environment Plan Measurements

Wetland environmental plans are a very important type of plan that relate to human welfare and safety.

The island of Taiwan has approximately 11,846 hectares of wetlands. Thus, a majority of coastal development is directly or indirectly related to wetlands, and development is typically in conflict with the preservation efforts of the wetlands.

Measuring wetland environmental plans involves a number of complex factors, including natural environment, ecological environment, physical environment, human environment, society, and economic issues. There have been considerable research discussions on the landscape of wetlands, the economy, water storage, management modeling, and scenario evaluation. How can the environmental problems of wetlands be solved? The wetlands environmental survey data revealed characteristic values that were used for improving and stabilizing the river canal shape, increasing the activities of biological communities, increasing mold habitats and regeneration, improving structural integrality of the ecological corridor, creating peripheral landscapes and natural environment features, developing tour facilities and resources of human industries, repeating the structural nature of beautiful material, increasing the value of tourism, and protecting the environment.

The four aspects of influence that must be considered in this research are: (1) natural environment; (2) ecological environment; (3) physical environment; and (4) human environment (including both social and economic aspects). Since comprehensive conservation rate in wetlands environmental plan system is an important factor in plan measurements, it was used as a further criterion (Table 2).

Table 2. Dimensions and Criteria for Wetlands Environmental Plan System

Dimensions	Influence Criteria	Statements of Influence Criteria
Natural Environment (D_1)	1. The degree of connection of river basin (C_1)	It indicates the degree of connection of river and other wetlands.
	2. Distribution of scenic resources (C_2)	The distribution is formed by climate, terrain, geological, hydrology, ocean current, zoology, botany ecology and so on.
	3. The impact and monitoring of environment (C_3)	Understand the impact and response on the ecological environment of the development of wetlands.
Ecological Environment (D_2)	4. The activity of biotic community (multiplicity) (C_4)	Carry on the investigation of wetlands' biology species, and understand the composition of region ecology.
	5. Recovery of habitat (molding and regeneration) (C_5)	The biology or the communities (aggregations) live at a habitat so as to construct a complete ecology corridor.
Physical Environment (D_3)	6. Improvement of water's quality (C_6)	The activity of improving water's quality: to take the pH value into consideration, to reserve the original mineral substance and to increase the level of containing oxygen and so on.
	7. Measure of decreasing floods (C_7)	Decrease the measure of preventing of floods.
Environment of Humanity, Society and Economy (D_4)	8. Analysis of the form of industrial distribution (C_8)	Analyze the condition of distribution of wetlands in accordance with current industry.
	9. Usage of land resources (C_9)	Indicate, under certain technical and economy condition, the land resources which can directly be used for human's production and existence, and bring benefits to humans.
	10. Analysis of villages (C_{10})	Analyze the regions which gather large population size.
	11. Ecology-tourism (science education) (C_{11})	Let people experience the importance of the maintenance of biological multiplicity by touring in order to achieve the goal of ecology preservation; thus, push ahead the coexistence and advance between ecology preservation and tourism industry.

3. A HYBRID NOVEL MCDM MODEL FOR EVALUATION AND PLANNING

The main objective of the Hybrid Novel MCDM model proposed in this thesis is environment Problems-Solving for achieving the aspired levels of human welfare, the model includes techniques of idea, logic reasoning, and thinking systems. The MCDM method is aimed at three major classifications: (1) Individual issues/objects evaluation using multivariate statistical analysis and data mining for data process analysis to understand the existing problems for future prospects; (2) Multi-criteria evaluation for selection or improvement, proposal to solve and analyze the problems with feasible alternatives for the "problems-solving"; (3) The identified problems are dealt with multi-objective programming for plan or design. The contents of this Hybrid Novel MCDM model are included in three parts as follows.

This study focuses on the hybrid novel MCDM method for decision making in regional environment. The first part of this section focuses on a method to build the analysis of a five hierarchy systems. The second part of this section focuses on utilizing fuzzy classification to solve the optimal strategy combination. Finally, a summary of some widely used cluster validity function for fuzzy classification is provided, the validity of which index could provide the useful information to determine the critical number of clusters.

Buliding an Analysis Hierarchy System for Evaluation and Planning

In this study, firstly a hierarchy system is established for analysis, evaluation, and planning through scenario writing and brainstorming. Phase 1 includes the overall objectives. Phase 2 the related aspects are considered for achieving goals. The list of criteria is considered in Phase 3, all criteria under consideration are measured using evaluators consisting of individuals with different viewpoints. Phase 4 involves a listing of alternatives/strategies for selection, and finally, the best plan will be selected in Phase5 (Figure 2).

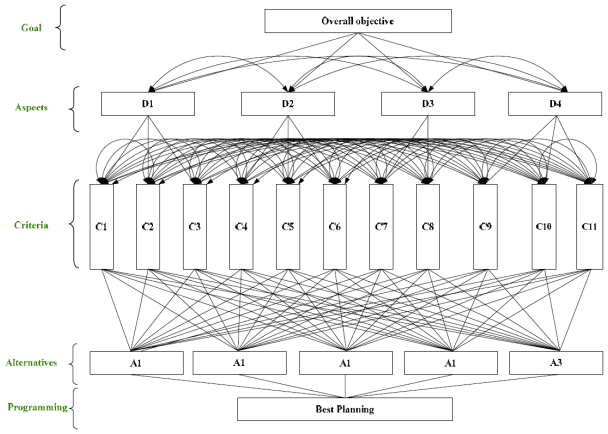

Fig.2. Analysis Hierarchy System for Evaluation and Planning.

Buliding MCDM Model for Regional Environment Plan Strategy

This paper establishes a regional environmental (watershed and coastal wetland) plan system that will exert an influence in the regional 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 regional environment and produce some impact on the regional environment. A watershed environmental plan must consider in detail watershed management and erosion control, ecological restoration, environmental construction, and environmental conservation; a coastal wetland plan must consider in natural, ecological, physical and human environment.

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. DEMATEL has been successfully applied in many situations such as marketing strategies, e-learning evaluations, control systems, and safety problems.

4. EMPIRICAL STUDY ON REGIONAL ENVIRONMENT PLANNING

By applying the multi-criteria decision making method to explore the proposed strategy seeking sustainable development, it is successfully demonstrated that these methods of measurement, improvement, and strategy, therefore it provides a good evaluation planning and appear to be more appropriate in the real regional environment of Taiwan. There are divided into three parts: In the first part, the measures and evaluation to build strategies are provided; in the second part, selection of the best alternative is presented; in the third part, allocation of the optimal resource is presented.

Case Study of the Pei-Keng Brook Envrionment-Watershed Plan Systems

Located in Taiwan, the study area is comprised of four parts. This planning includes the Guoxing town of Nantou County where the Nangang River of the town 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) (Figure 3). The plan systems are complex and are composed of environmental, software, hardware, and human factors.

Measuring Relationships among Dimensions for Building NRM

This study is aimed at determining the most important plan criteria as well as measuring relationships among criteria for building an NRM (network relation map). A questionnaire was provided to three groups which were comprised of 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 of each criterion with respect to sustainable development using a 5-point scale ranging from 5 (extremely important) to 1 (no effect). The three criteria with the highest scores were extracted from each dimension to construct the system for measuring the environment watershed plan. Since comprehensive conservation rate in environment watershed plan system is an important factor in plan measurements, it was used as a further criterion. The aim is to determine the most important plan criteria as well as measure the relationships among criteria. The watershed experts were thus asked to determine the importance of the relationships among the dimensions. The average initial direct-relation 4×4 matrix A obtained by pair-wise comparisons in terms of influences and directions between dimensions is shown in Table 3.

Table 3. 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

As seen in matrix A, the normalized direct-relation D is calculated from Equation (1) and (2). Subsequently, by using Equation (3), the total-influence T can be derived as shown in Table 4. Finally, using Equations (4) and (5), the sum of the total-influence given and received by each dimension can be derived as shown in Table 5.

$$D = kA \tag{1}$$

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

$$T = D(I-D)^{-1}, \text{where } k \to \infty, D^K = [0]_{nxn} \tag{3}$$

$$r = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1} = [t_i]_{nx1} = (r_1, \ldots, r_i, \ldots, r_n)' \tag{4}$$

$$c = \left[\sum_{i=1}^{n} t_{ij}\right]_{1xn} = [t_j]_{nx1} = (c_1, \ldots, c_j, \ldots, c_n)' \tag{5}$$

Table 4. 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)

Accordingly, the IRM of the DEMATEL method can be obtained as shown in Figure 3 using Table 4, and as shown in Figure 4 using Table 5.

Table 5. The Sum of Influence Given and Received on Dimension

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

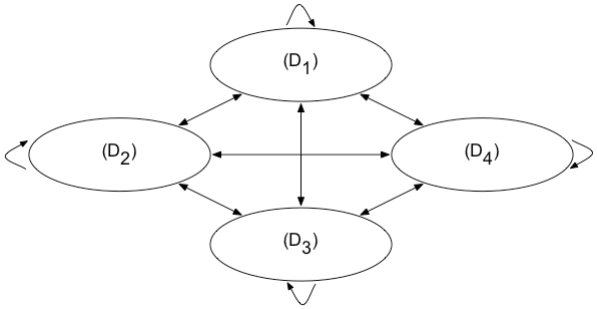

Fig.3. The Impact-Relationship-Map of Relations within Safety Systems.

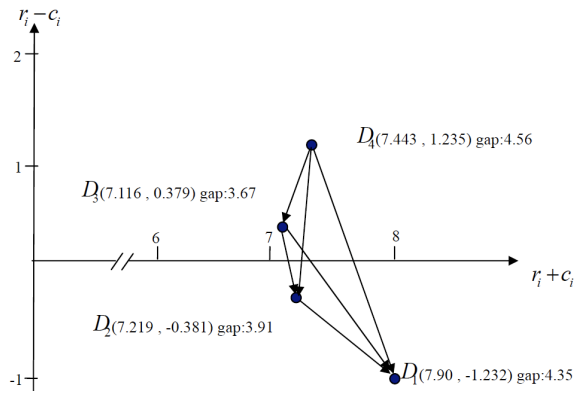

Fig.4. The Impact-Direction Map.

5. DISCUSSIONS FOR MANAGERIAL IMPLICATIONS

This research presented a plan for preserving environment watersheds and coastal wetlands by use of a novel hybrid MCDM method to address dependent relationships among criteria. By using a DEMATEL technique to construct the NRM, along with ANP to decide the relative weights of criteria, a selection plan was proposed in the environment watershed of a fuzzy decision support system for the assessment of alternative strategies.

The results of the empirical case are presented in section four. The discussion is divided into three parts and subsequently four subsections. Firstly, the measures and evaluation is to build strategies. Secondly, selection of the best alternative is highlighted. And thirdly, the optimal resource allocation is presented.

From the results obtained earlier, it is known that the DEMATEL can be used in conjunction with an ANP for determining the relative weights of the criteria. The DEMATEL works in an ANP to construct a new measurement model for environment watershed plan effects in an empirical study: (1) for evaluating Pei-Keng brook environments, and (2) for evaluating Kao-Mei coastal wetland environments. The result was obtained as follows:

In the Pei-Keng brook of watershed environment, the influence dimensions and criteria weight that represented the dimensions affected by the physical environment were calculated (Figure 4).

The environment watershed plan strategy is shown in

Table 6. It can reduce environment-watershed and emphasize the goal of a sustainable environment. The strategy and the program continue to question the use of expert interviews with key design, according to papers in section 2 of the structure to aggregate the characteristics of the dimensions and criteria. The watershed area of the Pei-Keng brook designed four items of ten issues and interviews with experts capable of successfully guiding a regional environment for the sustainable environment and living comfortable, safe environment for advice of the best planning.

Table 6. 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.

6. CONCLUSIONS

The present study established a hybrid causal model of the regional environment plan effect, the relational structure, selection of the best alternative, and resource allocation. The optimization design model was verified through satisfactory statistical techniques in order to confirm its efficiency for use in further researches. Traditionally, the plan is based on the number of storm water catastrophes, human environment criteria, usage of land resources, analysis of the form of industrial distribution, ecology tourism, the analysis of villages, and possibly “land and monitored” rates during audits.

Based on several aspects of environment watershed plan systems, the DEMATEL and ANP methods were combined to form a hybrid MCDM approach that considers interdependence among a range of criteria and their weighting.

The regional environment plan ranking indicates the criterion that has the best plan record in Pei-Keng brook watershed, Environmental Conservation, Environmental Construction, Ecological Restoration, Watershed Management and Erosion Control.

In the proposed model, DEMATEL was used for determining the influence factors and ANP was applied for determining the most important criteria / factors which will influence the efficiency of the environment watershed plan effect. The DEMATEL technique was used for comparing pairs of mutual relationships to the survey materials and for clarifying the essence of the problem.

An empirical testing of the approach was carried out using a Taiwanese case study, which illustrated its usefulness. Thus, the crux of the problem could be determined based on the novel hybrid MCDM model method. It can be concluded that the model is well suited for dealing with decision problems whose constructs are complicated and whose criteria are interdependent. It may help in making strategic plans for the Taiwan's Soil and Water Conservation Bureau and Council of Agriculture to conduct an annual plan for evaluations and an optimal project of the regional environment.

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