Environmental Engineering and Management Journal

September 2018, Vol.17, No. 9, 2031-2039
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

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PLANNING AND DECISION-MAKING MODELS IN ECOLOGICAL ENGINEERING APPLIED TO TAIWAN MID-WEST COAST

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Abstract

The aim of this study is to identify the influential factors which affect the planning and construction process in coastal ecological engineering. Through the application of AHP to analyze weight, it applies the data obtained from descriptive statistics as a reference in decision-making. Research methods are by means of expert questionnaire. To understand the same and different points of views from the experts and scholars, then according to different purposes it uses the results of this study in period of planning and decision-making process. For promoting coastal ecological engineering application in Taiwan mid-west, the study can also provide more scientific and convincing approaches. The results find out that due to safety requirements, experts and scholars are the highest standard on strength impact and implementation difficulty. However, increasing safety requirements for eco-friendliness is unfavorable. It needs some countermeasures to improve the habitat stability. In additional to the safety, the results also indicate that for habitat stability requirements can be used as an important reference for decision-making. Otherwhile, if coastal ecological engineering is focused on mutually beneficial coexistence between human and the environment, the different decision-making model will be considered.

Key words: abatement cost, emission intensity, fossil fuel power plant, primary air pollutant

Received: June, 2013; Revised final: December, 2014; Accepted: December, 2014; Published in final edited form: September, 2018

1. Introduction

The west coast of Taiwan is sandy terrain; especially in the central it has a vast muddy beach. There are diverse wetland ecosystems. So, compared with other regions, to promote ecological engineering has more convenience and practical needs. The mid-west coast has been constantly developed into a large-scale of coastal industrial park by government in the mid-west of Taiwan of Changhua, Yunlin and Chiayi Counties. According to government statistics, the proportion of natural coast in these three counties is only about 5%.

The problems the mid-west coast is facing now and the features are as following:

- Development of coastal industrial park;
- Wetlands gradually disappearing or becoming sandbar;
- Soil salinization caused by seawater invasion.

1.1. Development of coastal industrial park

The economic development in Taiwan was focused on manufacture industry from the 1960s. In order to develop the light industry, many of the Export Processing Zones were located in coastal area. Until the stage of development of heavy industry, the demand for land to build plants was more urgent. The area started from small blocks to large-scale industrial development zones. The rise land prices had increased the difficulty of land acquisition, making originally small but crowded regions in Taiwan mid-west more difficult to acquire land. In addition, the concept of

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environmental conservation has been taken seriously gradually. Series of assessment standards for environmental impact on land were formulated by Taiwan Government. This policy made an already shortage of usable land more difficult to obtain. Therefore, the Government actively developed reclaimed land especially in the mid-west region due to the case of sandy beaches and gentle slope.

1.2. Wetlands gradually disappearing or becoming sandbar

Export-Oriented industrial policy led to the development needs of harbors. In order to maintain the stability of harbor fairways, many breakwaters were built and became the killer of wetland ecosystem. Breakwaters blocking-up the sand drifting along the coast resulted in the gradual disappearance of original wetlands due to supplement of sand reduced. Breakwaters also blocked the coastal current and made the area in front of the breakwaters accumulating a large amount of sand which made the shoreline recede. Moreover, breakwaters not only blocked biological migration path and changed the ecological balance, but also caused serious ecological damage.

1.3. Soil salinization caused by seawater invasion

Beach disappearance has caused to lose natural barriers in many coastal areas. Seawater intrusion made the soil salinization behind the seawall. This result affected the economic activities in coastal areas as well as changed the protection of coastal plant ecology. The natural landscape alteration has also influenced the biodiversity around the areas.

In order to solve the problems faced in mid-west coast, this study has considered all procedures regarding planning, construction and subsequent maintenance, and then has divided the possible influence elements into five main eco-friendliness factors, including safety level, habitat stability, ecological restoration, landscape level, economic level. Each factor is further subdivided into several secondary factors through the relevant information collected of expert questionnaire. Then, the weight of impact among each factor is calculated through statistical software. That dates could be used as a very important reference during the period of planning and construction in coastal ecological engineering. That’s because coastal ecological engineering must pay attention to different terrains and consider the weather influence. Additionally the local ecological disturbance and destruction of the original landscape must also be considered. In order to involve civil society, investment must also be taken into consideration whether the ecological engineering might create economic benefits.

2. Literature review

Coastal ecological engineering has considerable values for the development of coastal areas (Baby et al., 2016). Both the largest natural resources and biological gene bank have close relationship with human survival and biological circulatory systems. Ray and Grassle (1991) argued that the genetic features of marine organisms are much more diversified than its land counterparts'.

Field et al. (1998) believed that 46% of the solar energy came from the diversified photosynthesis by the marine and near-shore organisms. Gowdy et al. (2000) divided the biodiversity values into two categories: the values to humans and the values to the ecosystem operations, and humans can only appraise the values based on the contributions biologic resources made to humans. But the ecosystem was severely affected due to human activities (Halpern et al., 2008). Carranza et al. (2009) discussed the dilemma of fisheries and conservationists. Waycott et al. (2009) discussed the seagrass value and threat by human activities.

Koch et al. (2009) used the non-linearity method different from the past to discuss the ecosystem services in coastal protection. Some studies put the focus on shoreline erosion effects on the value of ecosystem services (Alves et al., 2009; Chang et al., 2012; Roebeling, 2011, 2013). Soniat et al. (2012a) used the view of sustainable harvests to discuss restoration efforts and have proven success.

2.1. The direct use value of coastal ecosystem

Kaoru et al. (1995) and Barbier (2000) argued that valuation of the support functions of the coastal and near-shore areas had been concentrated on the economic values of the fishing-related services. Worm et al. (2006) argued that the collapse of the fishing industry would not only reduce the food supply, but also cause the decay of the marine ecosystem services. Heer (2002) studied the economic features of the marine ecology from the tourism viewpoint and concluded that easy accesses to coasts help attract tourists to visit, thus boost the metropolitan tourism. Phillips and Jones (2006) believed that tourism was the world's largest and fastest growing industry. Brander et al. (2007) focused on recreational value of coral reef for ecosystem services.

Ghermandi and Nunes (2013) focus on recreational benefits of coastal ecosystems to discuss its value. Seitz et al. (2013) discussed ecological value of coastal habitats from the perspectives of commerce and important species to.

2.2. The value of environment improvement brought from coastal ecological engineering

Duarte and Chiscano (1999) believed that about 15% of the global CO_2 was absorbed by seaweeds. Capone (2001) believed that the biological nitrogen fixation was even more important than the previously thought process of the nitrogen cycle, and could directly increase the oceans' CO_2 absorption capacity. Wattage (2011) estimated Economic valuation of ecosystem services from the coastal sustainable management.

2.3. Research tools

In this study, besides the application of descriptive statistical analysis, the main tool is AHP (Analytical Hierarchy Process) (Nouri et al., 2017). Barzekar et al. (2011) used this tool to prove ecotourism contribution to sustainable development. Lai and Vinh (2013) applied this tool to investigate tourism promotional effectiveness to Vietnam's economic development. Ghoshal (2013) used AHP to improve decision-making in investment portfolio. Akalin et al. (2013) used AHP to assess location selection. Tian et al. (2013) used AHP in sustainability assessment process for coastal beach exploitation. Sharifipour and Mahmodi (2012) also used it in decision comparison to environment management plan. Baby (2013) discussed the negative impact on coastal areas by human interventions and sprawling activities to help law maker to establish right policies. Murali et al. (2013) used AHP to discuss the elements which made coastal vulnerability.

3. Experimental

The composition of the questionnaire contents is to use Delphi method. The experts and scholars as the source of the questionnaire reference options were chosen from the Taiwan Coastal Engineering Association annual meeting held from 2010 to 2012, for those well-known experts with engineering practices, and the scholars have published researches presented in thesis seminar. The initial questionnaire is to take interviews to collect question responses, and then take anonymous and semi-open way to answer questions. In addition to inquiries of experts and scholars expressing opinions for agreement or disagreement, there were identified questions and they were allowed them to add personal opinions. After collecting and collating form a new questionnaire, it further requests the same experts and scholars' re-answers. The formal questionnaire was identified until consensus consistency was obtained, then the formal questionnaire was presented to 30 anonymous experts and scholars. The process repeated several times, until the individual topic and the overall consistency of the questionnaire were done.

3.1. Descriptive statistical analysis

The impact strengths and implementation difficulties were divided into five levels, from 1-5, the higher the number represents that impact strength and implementation difficulties are higher. The statistical results are shown in Table 1.

3.2. AHP analysis

We use the numbers 1-9 to represent the relative importance between two influential factors. The higher the number represents the relative importance is higher. This study must compare all the main and secondary influential factors by pairwise comparison method to analyze their relative importance. For example, "Safety related Habitat Stability=9:1" represents the "Safety" is the more important than the "Habitat Stability". The "Weight" means the relative degree of importance. The statistical result is shown in Table 2.

3.3. The eco-friendliness equations

The eco-friendliness equations with the weights of the main influential factors are shown below, and the correlations of the main influential factors are depicted in Fig. 1.

From Fig. 1 shown if safety level is raised, thus the eco-friendliness should decrease. In order to maintain the original level, the other influential factors must also be raised. By the same token, if safety level is lowered, the others must also be lowered.

Table 1. The impact strengths and implementation difficulties of the influential factors

Main factor	***Secondary factor***	***Strength***	***Difficulty***
Safety level ($\mathbf{x_1}$): Engineering method and safety for the protection of the neighborhood properties and lives.		3.9	3.2
	Foundation stability ($\mathbf{x_{11}}$): Stabilized foundation can resist the damages from the once-in-fifty-years storm surge and land subsidence.	3.7	3.1
	Anti-erosion ($\mathbf{x_{12}}$): The works can resist erosion damages from the near-shore currents and coastal currents.	3.6	3.1
	Durability ($\mathbf{x_{13}}$): Under the circumstances of no safety concerns, the durability can last for at least 50 years.	3.5	3.2***
Habitat stability ($\mathbf{x_2}$): Reducing interference with habitats during and after the constructions for the protection of biodiversity.		3.4	2.4
	Whether the habitat is strongly interfered by constructions ($\mathbf{x_{21}}$): Reducing short-term turbulence and pollution resulted from construction interference.	3.6***	2.6
	Habitat ecology undergoes tremendous impacts and the biodiversity is changed ($\mathbf{x_{22}}$): Avoiding improper engineering design that may alter the existing ecologic balance in the habitat, thus lead to changes in the number of species.	3.7	2.6
	Constructions block the ecologic corridor and lead to loss of species ($\mathbf{x_{23}}$): Avoiding construction facilities that block the biologic migration paths and cause biologic distinction because of changed living patterns.	3.9	2.8

Ecological restoration level (x_{3}): Using well designed engineering method to restore the ecosystem from the construction interference and making the eco-environment even more flourishing.		3.4	2.7
	Surface porosity (x_{31}): Design of the structure surface to provide habitats for fouling organisms to form excellent algae fields.	3.9	3.5
	Terraced dike design (x_{32}): compound structure design to lower the height, thus reduce impacts on the ecology.	3.1***	3.2
	Slope gentleness (x_{33}): Using gentle slope design to reduce the run-up wave impact on the structure.	3.7	3.2
	Material naturalization(x_{34}): Using materials of nature or available at the construction site to minimize the changes made to the environment.	3.5	2.9***
	Interface permeability(x_{35}): Good permeability helps water conservation and purification.	3.7	3.2
Landscape level (x_{4}): Avoiding too much artificial landscape that may affect the scenic views and people's intimacy with the waters, and making regions integration for overall design and planning.		3.4	3.6
	Hydrophilic level (x_{41}): Hydrophilic space helps people come close to nature.	4.0	3.6
	Near-nature (x_{42}): The engineering design should be seriously taken into account the natural environment in order to keep the original landscape intact.	3.9	2.9
	Aesthetic greening consideration (x_{43}): Using the greening and aesthetic design to minimize the impacts on the original landscape, and even making the environment better than ever.	3.7***	3.6
	Environmental fusion (x_{44}): Blending with the neighboring landscape to create added values of the construction.	3.6	3.4
Economic level (x_{5}): Reducing construction and maintenance costs and creating leisure and recreational space to increase the economic values of the ecology.		3.4	3.1
	Maintenance and management difficulty (x_{51}): Minimizing the after-construction maintenance and management costs.	3.6	2.7
	Construction method and materials costs (x_{52}): Lowering the construction and material costs.	3.4	2.8
	Eco-tourism benefits (x_{53}): Increasing the real benefits with the creation of the eco-tourism space.	3.2***	2.7
	Ecologic benefits from sustainability (x_{54}): Increasing the use and nonuse values from the environmental management.	3.5	3.0

*(Note) *** stands for the significant difference reached with 95% confidence level*

Table 2. Influential factors' weight coefficient (AHP)

Influential factors	***Coefficients***	***Weights***		
		The all	***Scholars***	***Experts***
x_{1}	a	0.278	0.259	0.298
x_{2}	b	0.273	0.307	0.237
x_{3}	c	0.215	0.204	0.228
x_{4}	d	0.128	0.129	0.126
x_{5}	e	0.106	0.101	0.112
x_{11}	a_{1}	0.412	0.452	0.354
x_{12}	a_{2}	0.349	0.319	0.393
x_{13}	a_{3}	0.239	0.229	0.253
x_{21}	b_{1}	0.153	0.122	0.200
x_{22}	b_{2}	0.335	0.424	0.221
x_{23}	b_{3}	0.513	0.454	0.579
x_{31}	c_{1}	0.225	0.183	0.280
x_{32}	c_{2}	0.101	0.080	0.134
x_{33}	c_{3}	0.205	0.177	0.244
x_{34}	c_{4}	0.295	0.338	0.227
x_{35}	c_{5}	0.173	0.222	0.115
x_{41}	d_{1}	0.199	0.187	0.218
x_{42}	d_{2}	0.298	0.327	0.255
x_{43}	d_{3}	0.225	0.232	0.213
x_{44}	d_{4}	0.278	0.254	0.314
x_{51}	e_{1}	0.336	0.281	0.425
x_{52}	e_{2}	0.147	0.115	0.192
x_{53}	e_{3}	0.169	0.186	0.138
x_{54}	e_{4}	0.347	0.418	0.244

(Note) under the level of overall inconsistency index less than 0.1

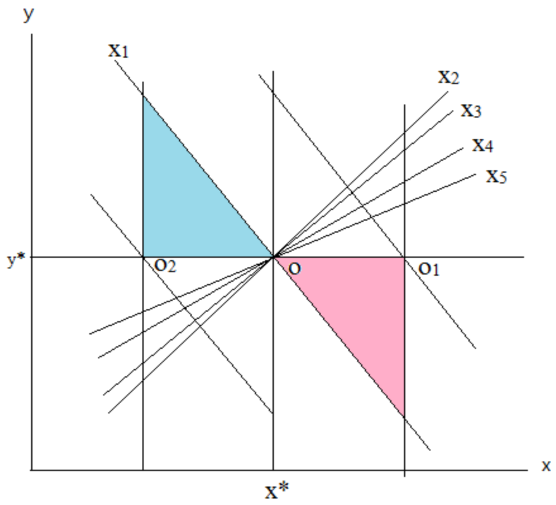

Fig. 1. Main influential factors equilibrium analysis

$$y=a(a_1x_{11}+a_2x_{12}+a_3x_{13})+b(b_1x_{21}+b_2x_{22}+b_3x_{23})+ \\ c(c_1x_{31}+c_2x_{32}+c_3x_{33}+c_4x_{34}+c_5x_{35})+ \\ d(d_1x_{41}+d_2x_{42}+d_3x_{43}+d_4x_{44})+ \\ e(e_1x_{51}+e_2x_{52}+e_3x_{53}+e_4x_{54}) \quad (1)$$

3.4. The relationship between eco-friendliness and safety level

According to the influential factor's weight coefficient,

$$y=f(x_1,x_2,x_3,x_4,x_5) \quad (2)$$

Assumed that all the factors other than the safety level remain unchanged:

$$\frac{\partial y}{\partial x_1}=a\prec 0$$

$$\frac{\partial x_1}{\partial t}=\prec 0 \quad (3)$$

$$\therefore \frac{\partial y}{\partial x_1}\cdot\frac{\partial x_1}{\partial t}\succ 0\Rightarrow\frac{\partial y}{\partial t}\succ 0 \quad (4)$$

Similarly can be obtained:

$$\frac{\partial y}{\partial x_2}=b\succ 0,\ \frac{\partial y}{\partial x_3}=c\succ 0,$$

$$\frac{\partial y}{\partial x_4}=d\succ 0,\ \frac{\partial y}{\partial x_5}=e\succ 0$$

$$\frac{\partial x_2}{\partial t}\succ 0,\ \frac{\partial x_3}{\partial t}\succ 0,\ \frac{\partial x_4}{\partial t}\succ 0,\ \frac{\partial x_5}{\partial t}\succ 0 \quad (5)$$

The results from Eq. (4) and Eq. (5), can be expressed as Eq. (6):

$$\therefore \frac{\partial x_1}{\partial t}\cdot\frac{\partial t}{\partial x_2}\prec 0\Rightarrow\frac{\partial x_1}{\partial x_2}\prec 0$$

$$\frac{\partial x_1}{\partial t}\cdot\frac{\partial t}{\partial x_3}\prec 0\Rightarrow\frac{\partial x_1}{\partial x_3}\prec 0$$

$$\frac{\partial x_1}{\partial t}\cdot\frac{\partial t}{\partial x_4}\prec 0\Rightarrow\frac{\partial x_1}{\partial x_4}\prec 0$$

$$\frac{\partial x_1}{\partial t}\cdot\frac{\partial t}{\partial x_5}\prec 0\Rightarrow\frac{\partial x_1}{\partial x_5}\prec 0 \quad (6)$$

In addition, from Eq. (7) as below:

$$\frac{\partial y}{\partial x_2}\cdot\frac{\partial x_2}{\partial t}\succ 0,\ \frac{\partial y}{\partial x_3}\cdot\frac{\partial x_3}{\partial t}\succ 0$$

$$\frac{\partial y}{\partial x_4}\cdot\frac{\partial x_4}{\partial t}\succ 0,\ \frac{\partial y}{\partial x_5}\cdot\frac{\partial x_5}{\partial t}\succ 0 \quad (7)$$

$$\therefore \frac{\partial y}{\partial t}\succ 0$$

From here, we obtain the same result as Eq. (4). The eco-friendliness equations with the weights of the main influential factors are shown below, and the correlations of the main influential factors are depicted in Fig. 2 (we assumed a negative correlation between “eco-friendliness” and “economic level” here; the real situation must be based on results of Eq. (10) or Eq. (16)).

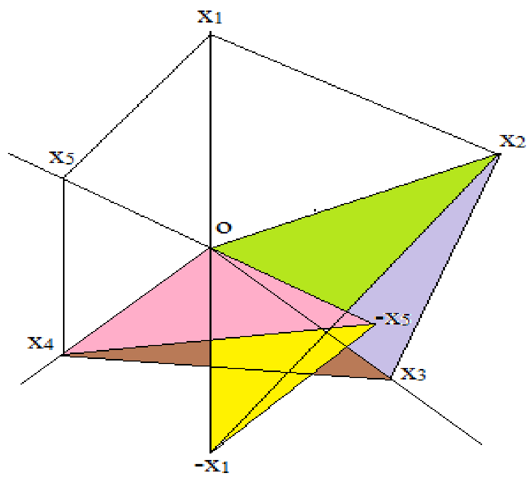

Fig. 2. The dynamic equilibrium of eco-friendliness with the main influential factors

3.5. The analysis with the second secondary influential factors of economic level

According to the influential factor's weight coefficient,

$$x_5=f(x_{51},x_{52},x_{53},x_{54}) \quad (8)$$

$$\frac{\partial x_5}{\partial x_{51}}\prec 0,\ \frac{\partial x_5}{\partial x_{52}}\prec 0,$$

$$\frac{\partial x_5}{\partial x_{53}}\succ 0,\ \frac{\partial x_5}{\partial x_{54}}\succ 0 \quad (9)$$

3.5.1. Present value of annuity (PV)

Under the circumstances of no safety concerns, the durability can last for at least 50 years. Where "PMT"refers to annuity payment each year; "i " refers to interest rate.

From the results Eq. (6) shown, using PV method converts the maintenance and management cost into present value, and then adds engineering and material costs. If total cost is greater than the benefits of eco-tourism and ecological sustainability, the value of economic level is positive, otherwise it is negative.

$$PV_{i,50} = PMT \cdot \left[\sum_{t=1}^{50} \frac{1}{(1+i)^t} \right]$$

$$\therefore x_5 = -(\sum_{1}^{50} x_{51}) - x_{52} + \sum_{1}^{50} x_{53} + \sum_{1}^{50} x_{54} \quad (10)$$

$$\text{if } (-(\sum_{1}^{50} x_{51}) - x_{52}) \succ (\sum_{1}^{50} x_{53} + \sum_{1}^{50} x_{54}) \quad (11)$$

$$\textit{then } x_5 \succ 0, \quad \textit{otherwise } x_5 \prec 0$$

3.5.2. The benefits and costs method

"Tc" refers to total cost; "Fc" refers to total fixed cost; "Vc" refers to total variable cost; "T_R" refers to total revenue.

The relationship curve between costs and benefits is depicted in Fig. 3.

$$E_R = \int_{X_1}^{X_2} [f(x) - g(x)]\, dx \quad (12)$$

$$S_R = \left\{ \int_0^{X_1} [g(x) - f(x)]\, dx + \int_{X_2}^{50} [g(x) - f(x)]\, dx \right\} \quad (13)$$

$$T_C = F_C + V_C = g(x) \quad (14)$$

$$T_R = E_R + S_R = f(x) \quad (15)$$

$$\textit{if } \int_{X_1}^{X_2} [f(x) - g(x)]\, dx -$$

$$\left\{ \int_0^{X_1} [g(x) - f(x)]\, dx + \int_{X_2}^{50} [g(x) - f(x)]\, dx \right\} \geq 0 \quad (16)$$

$$\textit{then} \quad x_5 \geq 0 \quad \textit{otherwise} \quad x_5 \prec 0$$

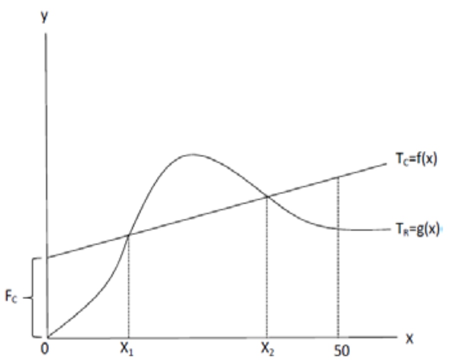

Fig. 3. The relationship curve between costs and benefits

The economic level equations with the weights of the secondary influential factors are shown above, and the correlations of the secondary influential factors are depicted in Fig. 4.

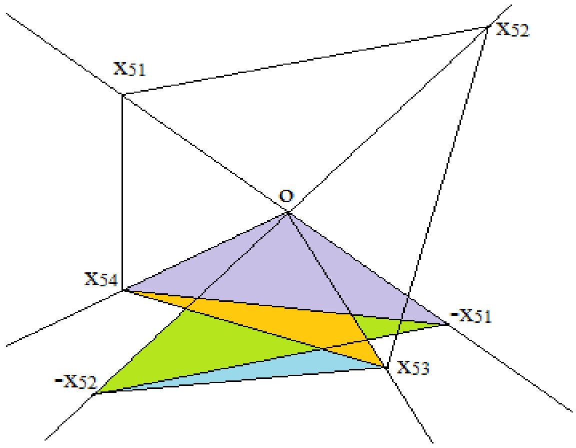

Fig. 4. The dynamic equilibrium of economic level with its secondary influential factors

3.6. The planning and decision-making

3.6.1. The decision-making on safety level

To all the questionnaire respondents, the safety level has the highest impact strength and greatest implementation difficulty. And the test result also shows no significant differences between the scholars and engineering experts. Table 3 below displays the major possible decision-making models.

Table 3. The decision-making and analysis of the main influential factors

x1	*y*		*x2*	*x3*	*x4*	*x5*
↑	↓	Impact	↑	↑	↑	↑
		Decision priority	**1**	**2**	**4**	**3**
↓	↑	Impact	↓	↓	↓	↓
		Decision priority	**4**	**3**	**1**	**2**

The decision-making on the secondary influential factors as following:

3.6.1.1. Safety level ↑

As a result, the anti-erosion should be listed as the first priority, following by foundation stability (x_{11}). For secondary influential factors, the "Loss of species due to the constructions blocking the ecologic corridors" (x_{23}) has the maximum weight and low implementation difficulty, which should be given the highest priority, following by the "Biodiversity change due to tremendous impacts on the habitats" (x_{22}). See Table 4 for the results.

3.6.1.2. Safety level ↓

The durability (x_{13}) has the lowest influential weight. As a result, in consideration of lowering the safety level, lowering durability should be taken as the first priority.

As for the other secondary influential factors that can lower the safety level, the hydrophilic level (x_{41}) that comes with the similar weight but much higher implementation difficulty should be the first choice. It can go with the environmental fusion (x_{44}) whose weight is not high while implementation difficulty is relatively high. The second choice is the aesthetic greening consideration (x_{43}). See Table 5 for the analysis results.

3.6.2. The decision-making on habitat stability(x_2) ↑

Excluding the safety level, the habitat stability (x_2) has the lowest implementation difficulty as well as reduces the future "restoration" and "compensation" costs on the ecologic environment.

Among the secondary influential factors of habitat stability (x_2), "Loss of species due to the constructions blocking the ecologic corridors" (x_{23}) has the highest weight in affecting the coastal eco-engineering, even though it is placed third in the overall weight ranking. Therefore, it can be given the highest priority.

Upon increasing the habitat stability, the terraced dike design (x_{32}) with low influential strength and a bit higher implementation difficulty is an ideal object for lowering the ecologic impact, which can be given the highest priority.

As for the second priority, the "Ecologic benefits from sustainability" (x_{54}) is targeted. The analysis result is shown in Table 6 below.

If we put ecological protection as a priority for decision-making, the aesthetic greening consideration (x_{43}) becomes a discourse focus. The aesthetic greening is not an equivalent to eco-engineering, but such effects can be easily achieved by other means, for example, the terraced dike design (x_{32}), the dike slope gentleness (x_{33}) or the material naturalization (x_{34}).

From the eco-conservation point of view, the eco-tourism benefits (x_{53}) and benefits from ecologic sustainability (x_{54}), the revenues created from the eco-engineering can offset some of the engineering costs. Therefore, they can be used to replace the benefits from ecologic sustainability (x_{54}). The analysis result is shown in Table 7.

4. Results and discussion

4.1. With the descriptive analysis and the distribution analysis, this study obtains the following results:

(1) Safety level is the key point of the whole eco-engineering

Looking into the analysis of the main influential factors, the impact strength of all five factors reaches 3.4 above, where safety level is as much as 3.9(maximum is 5.0). The results show that four other factors have also been considerably noticed, comparing with the past that only concerned about safety issues but ignoring ecological protection has been improved.

(2) "Maintaining habitat stability" is regarded as not difficult in the engineering practices.

In this respect, the views of experts and scholars are the same. From the further importance of secondary factors, the experts also agree that during the executed engineering, biological habitat will be disturbed, but the intensity is better than the change in the biodiversity and species loss.

(3) The impact strength and implementation difficulty of the "surface porosity" on the ecological restoration are the highest.

The reason is that the degree of porosity in structures surface is an important factor affecting coastal plankton and phytoplankton growth. For example, the concept of artificial reef balls was used to design the coastal engineering structures.

Table 5. Dependent variables in response to the fall of the safety level

	Independent variable		***Dependent variable***			
Secondary influential factor	x_{13}	x_{12}	x_{41}	x_{44}	x_{43}	x_{32}
Influence	↓	↓	↓	↓	↓	↓
Decision sequence	**1**	**2**	**1**	**1**	**2**	**3**

Table 6. Decision-making based on the "Loss of species due to the constructions blocking the ecologic corridors" as the main variable

	Independent variable	***Dependent variable***	
Secondary influential factor	x_{23}	x_{32}	x_{54}
Influence	↑	↓	↓
Decision sequence	**1**	**1**	**2**

Table 7. Decision making on the premise of eco-conservation

	Independent variable	Dependent variable		Extended variable	
Secondary influential factor	x_{23}	x_{43}	x_{52}	x_{53}	x_{54}
Influence	↑	↓	↓	↑	↑
Decision sequence	**1**	**1**	**2**	**1**	**2**

(4) On the influential strengths of "aesthetic greening consideration" and "eco-tourism benefits", the scholars and engineering experts have different views.

Scholars believe that investment in coastal ecological engineering is worth, compared with the environmental conservation contribution. They expect that through the ecological environment creation and management may get the use and non-use values, and it generates substantial economic benefits through the green concept of ecotourism.

4.2. With the AHP analysis, this study obtains the following results:

(1) Appropriately raising the "safety level" does not necessarily bring negative effects on the protection of the coast ecologic environment.

From the descriptive statistics results, the implementation difficulties for habitat stability are significantly lower than the safety level. Therefore, a small margin of safety requirements increases, compared with decreasing the degree of eco-friendliness. This is not obvious.

(2) The "hydrophilic level" and "aesthetic greening consideration" are controversial in eco-technology.

Compared with the cost of engineering, the green landscaping expenditure is actually quite low and easy to implement. But for scholars, the concept of green landscaping doesn't mean ecological engineering. The green landscaping can not increase the space of habitat, either.

The designs of hydrophilic space allow humans to have the opportunity to get close to the natural environment. But if the space cannot be effectively distinguished for human or wildlife activities, it will result in another ecological catastrophe.

(3) The cause of habitat disturbance during construction period is not being taken seriously

The construction interference to habitat stability, compared with other secondary factors, is significantly lower. The most possible reason engineering experts think is that more can be done to reduce the impact of habitat disturbance through mitigation measures, such as to avoid and narrow scope.

5. Conclusions

The study results are summarized into the following conclusions:

(1) Concerns about eco-engineering remain focused on whether the engineering per se can meet up with the safety requirements.

This paper presents whether the experts or scholars, safety requirements are being placed on priority in coastal ecological engineering planning and design. The main reason is that the safety factor is able to control better along with taking care of the life and property of residents behind the embankment and in present engineering technology. Therefore, experts and scholars believe that to maintain the stability of habitat is not difficult.

(2) Eco-engineering should at least examine closely for the landscape requirements to satisfy the human needs on the "hydrophilic level" and "close to nature".

In all main factors, landscape level is considered to be the most difficult to implement. But in the AHP analysis, the weight is the lowest. The main reason is that most people still think greening and landscaping are the same concepts with ecological engineering. But, near-shore leisure activities have become one of the important tourism ways in Taiwan. How to create a friendly hydrophilic space and make people have a chance to get close to the sea should be seriously considered.

(3) From the perspective of "ecology restoration", the construction design and the material selection have difficulties in substantial implementation, indicating that materials for eco-engineering need further improvements or more replacements.

Coastal Ecological Engineering Materials used must do no harm to the local environment. Otherwise, it will destroy the original ecological stability. The mid-west coast is sandy terrain, breakwaters blocking-up the sand drifting along coast, so the materials used must be obtained from elsewhere and it is unfavorable to the ecological restoration. Also, what kind of engineering design is more favorable to ecological restoration? There is still no clear answer so far. Consequently, how to promote coastal ecology engineering in Taiwan requires a lot of effort.

(4) The different viewpoints between the engineering experts and the scholars will inevitably bring about negative impacts on eco-engineering.

In the study, we realize many distinct perspectives from experts and scholars. For example, in the ecological restoration, the experts believe that the implementation difficulty is not high, while the scholars think it is not an easy task. The main reason is the diverse cognitions in ecological engineering. This result for the promotion of coastal ecology engineering in Taiwan is unfavorable.

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