DISCUSSION OF ENVIRONMENTAL EDUCATION BASED ON THE SOCIAL AND CULTURAL CHARACTERISTICS OF THE COMMUNITY–AN MCDM APPROACH

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Abstract. Because of its geographic location, local characteristics and interconnections among its members, a community is often the basic unit for policy advocacy and implementation. With the worsening environmental pollutions nowadays around the world, problems such as greenhouse gas emissions, climate change, melting polar ice, and endangered species all demand the most urgent attention. In particular, high CO_2 emissions have caused unpredictable climate anomalies and disasters, posing as a severe and direct threat to the lives and properties of some people in the world. It is now an urgent priority to arouse higher awareness of the importance of environmental protection through education. In this study, the multi-criteria decision making methods of Analytical Hierarchy Process (AHP) and the quantification functions of fuzzy logic theory are used to build a quantitative evaluation model for community-based environmental education.
Keywords: *environmental pollutions, climate change, high CO_2 emissions, Analytical Hierarchy Process (AHP), fuzzy logic theory, evaluation model*

Research background and motivation

Due to the necessity of economic development, humanity are continuously polluting and damaging the natural environment, pushing nature to fight back with accumulated force. Even though the retaliation of nature has not directly endangered the life and property of everyone on earth, worsening climate disasters have forced each country to face the problems caused by man-made damage to the environment. According to Storm Media (2016), a super heat wave hit India and drove the temperature to 48°C. According to Sina, the temperature in the US hit an unprecedented 50°C and four died of heat stroke. As indicated in the report recently publicized by NASA and NOAA in the US, the average global temperature in May 2016 was 15.67°C, 0.87°C higher than the average in the last century, making it the warmest May ever recorded since 1880. In addition, the last 13 months, including May, have set a new record as the longest warm season. The US, Canada, Mexico, Central America, South America, North Europe, Asia and many other places around the world are experiencing higher temperature. According to the prediction by NOAA, this year will be the hottest year ever recorded in the world (Sina, 2016). Another climate disaster brought by climate change is storm flood. According to the report by on.cc on July 2nd this year(ON.cc., 20160703), severe storm floods hit Hubei Province in China, trapping a large number of villagers in floods and forcing 12,000 in six villages to evacuate(ON.cc., 20160702). One day later, another report by on.cc indicated the second flood peak was formed, posing a

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significant threat for the agriculture, lives and properties in the middle and lower reach of Yangtze River.

Higher concentrations of CO_2 in the atmosphere have trapped more solar heat and caused the so-called greenhouse effects, driving up the temperature and causing significant environmental impact (Fretzer, 2016; Jacob et al., 2016). There are a growing number of data and disastrous cases showing the connections between climate change and climate disasters and the serious economic losses and life threats brought by climate disasters (Hsueh, 2015). Climate change is also adverse to the ecological biodiversity (Hand et al., 2016; Wheeler et al., 2016). High CO_2 emissions have caused serious climate change around the world (De Souza and Mirazón Lahr, 2015). Taiwan is no exception. Since March 2015, Taiwan has seen the worst droughts and water shortage in 60 years. In September 2014, the temperature in Taiwan set a record high in 100 years. Similar climate disasters can be found in other parts of the world, such as the worst storm and floods in 12 years in Sydney, Australia in April 2015 (Sin Chew Daily, 2015) and the prediction of the worst blizzard in New York since 1873 (United Daily News, 2015). The problems of high temperature and floods are more serious this year. Despite such a large quantity of climate disasters, the population affected by these disasters is limited and most people around the world still could not perceive the urgency of the problems and they are indifferent to the disastrous consequences that extreme weather can bring. Therefore, it is not easy to change their wasteful energy consumption attitudes and behaviors. However, it is still urgent for each country to prepare now for more serious consequences brought by extreme weather in the future.

Humanity has been exploiting the natural environment for economic growth, industrial and business development, and satisfaction of personal desires. If the governments, economic departments, businesses and ordinary people fail to put the environment before economic and industrial development, warnings or suggestions from scientists and experts will still not work no matter how many more high-level international meetings to be held. High CO_2 emissions and climate change are indeed endangering people’s lives and properties. Hopefully, with the Paris Climate Agreement passed in 2015, the trend of global warming will be stalled and even reversed.

The problems of extreme weather and climate disasters require sufficient attention and preparation. In Taiwan, due to the shortage of electricity during scorching summer, issues such as reactivation of a closed nuclear power plant, energy conservation and green energy development have received a lot of attention; however, there is little public discussion about high CO_2 emissions and climate anomalies. Even though there are frequent incidents of extreme weather around the world, there are still some people and businesses who think climate change and high CO_2 are not directly correlated. Those businesses and people who are not affected by climate disasters are indifferent to the damage caused by these disasters and keep on pursuing their revenue growth or satisfaction of their material desires. Therefore, it requires environmental education to promote awareness of the personal social responsibility and corporate social responsibility for the environment (Hsueh, 2012; Streimikiene et al., 2009).

A community is a circle of people who share the same attributes of geographic location, production activities, landscape, industrial development, and social/cultural characteristics. Therefore, it is easy for people within a community to develop close interpersonal connections and their local characteristics. Environmental education based on the characteristics of a community is helpful for its sustainable development as a

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green community. A successful example is the community rebuilding and green development of Furukawa in Japan based on its social and cultural characteristics. Therefore, the community is the ideal unit for the development of a livable city. During the recent years, Taiwan has been proactively incorporated CO_2 emission reduction into community-based environmental protection policies such as the policy of forest plantation (Cabarga-Varona et al., 2016) with the purpose of improving air quality and building carbon stock of trees and providing incentives for plant diversity in idle spaces and parks within communities (Mardari and Tănase, 2016). Other policies provide incentives for green roof installation, roof-top solar power generation, and replacement with water-saving/power saving facilities. Despite these community-based environmental policies, the overall environment in Taiwan has not demonstrated significant improvement over the past recent years. Therefore, it is proposed in this study to improve the results of the community-based environmental policies and promote the sustainable development of green communities in Taiwan through environmental education based on the social and cultural characteristics of the communities. The multi-criteria decision making methods of Analytical Hierarchy Process (AHP) and the quantification functions of fuzzy logic theory are used in this study to build a model that can evaluate and explore decisive factors of successful community-based environmental education and then provide references for the making and implementation of community-based environmental policies.

Literature review

Community-based environmental education

Over the past years, the government in Taiwan has promulgated several environmental protection laws and policies to curb environmental pollution. For example, the Environmental Education Law was enacted to promote awareness about environmental protection through courses given by professional lecturers of environmental education. In addition, in accordance with the Law, environmental education is incorporated into school curricula for better effects of environmental education. At the beginning of the implementation of the Law, a national assessment of school teachers’ environmental literacy was performed in order to establish the baseline for evaluating the effectiveness of environmental education policy (Liu et al., 2015). The schools at each level in Taiwan are at the frontline of environmental protection education for the teachers and students generally have good emotional connections with one another. Emotions are important aspects in/for the pedagogy of environmental education, an outcome of effective instructional models designed to instill an environmental consciousness in students (Reis and Roth, 2009).

In addition, successful community building fundamentally depends on good interpersonal relationships among community residents. The key to successful promotion of environmental protection education in a community lies in the participation of community residents (He et al., 2013). Higher willingness among community residents to participate in environmental education will expand the education’s influence through their interpersonal connections. Community building has always played an important role in urban development in Taiwan. Based on the social and cultural characteristics of the community, advocacy of environmental protection policies will attract more community members to participate in the policy

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implementation. The advantage of community-based environmental education lies in the use of good interpersonal connections among community residents to boost public participation and win their trust in the polices for more effective policy advocacy and implementation.

Key factors of community-based environmental education

In addition to community residents' participation, promotion of higher awareness about environmental protection among community residents is also an extremely factor of community-based environmental education. Therefore, community-based environmental education should also incorporate local characteristics of the community and main themes of related governmental policies, such as renewable energy education (Kandpal and Broman, 2014), forest plantation, plant diversity, roof-top solar power generation, green roof, garbage reduction, biodiversity, greenhouse effect, climate change, energy conservation and carbon emission reduction. In the literature collected in this study on factors of community development and community-based environmental education, the study of Goralnik and Nelson (2011) indicates education can help to improve people's ethical behaviors. Therefore, regular advocacy and activities are very important for community-based environmental education. In addition, volunteerism, public participation and environmental awareness (Smith-Sebasto, 1992) are also important factors of successful community-based environmental education. Last but not least, the sources of funding is also a necessary factor for consideration.

Research method and design

Analytical hierarchy process (AHP)

AHP is a multi-criteria decision making (MCDM) model. It was first developed by Saaty using the formula of pairwise comparison. The AHP formula and calculation steps are illustrated in *Fig. 1*. In AHP, each criterion is compared against the other criteria. The comparison of every two criteria is based on data from the AHP questionnaire survey. The questionnaire data are rated from 1 to 9 according to their relative importance while only data with a consistency index of one or lower (C.I. $\leqq 1$) and a consistency ratio of 0.1 or lower (C.R. $\leqq 0.1$) are valid. The implementation procedure of AHP is illustrated in *Fig. 2*. Through the AHP formula, the relative weight value can be determined to provide references for AHP decision-making analysis. AHP has been widely used in different fields. In this study, AHP is used as a management decision-making model for the following matters (Saaty, 1980; Saaty and Vargas, 1991):

(1) Determination of the priorities of alternatives;
(2) Selection of the best alternatives from multiple alternatives;
(3) Selection of the best or most suitable alternative;
(4) Policy analysis and risk evaluation of different issues;
(5) Optimal distribution of limited resources;
(6) Alternative evaluation and incident prediction to provide references for policy making;
(7) Management performance evaluation in different fields;
(8) Optimal design evaluation in system design process;

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(9) System stability evaluation and system security assurance in system design;
(10) Selection of the best planning evaluation; and
(11) Conflict resolution and damage reduction.

(1) Pairwise comparison against

$$A = \left(a_{ij}\right) = \begin{pmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & 1 & & \cdots & a_{2n} \\ \vdots & \vdots & \cdot & \cdot & \vdots \\ a_{n1} & a_{n2} & & \cdots & 1 \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ 1/a_{12} & 1 & & \cdots & a_{2n} \\ \vdots & \vdots & \cdot & \cdot & \vdots \\ 1/a_{1n} & 1/a_{2n} & & \cdots & 1 \end{pmatrix}$$

(2) Priority vector：

$$W_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n} \Bigg/ \sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}$$

(3) Maximum priority vector：λ_{max}

$$\lambda_{max} = \left(a_{ij}\right) \begin{pmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{pmatrix} = \begin{pmatrix} W_1' \\ W_2' \\ \vdots \\ W_n' \end{pmatrix}$$

$$\lambda_{max} = (1/n)*(W_1'/W_1 + W_1'/W_1 + \cdots + W_1'/W_1)$$

(4) C.I. ≦1 ; C.R. ≦0.1

$$\text{C.I.} = \frac{\lambda_{max} - n}{n - 1} \quad \& \quad \text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}}$$

Figure 1. *AHP formula and calculation steps*

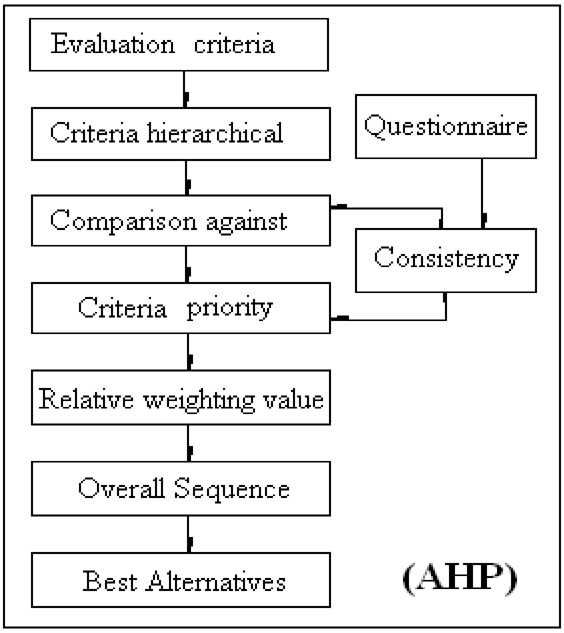

Figure 2. *AHP implementation procedure*

AHP modeling and key factors

The multi-criteria decision making (MCDM) model of AHP in this study is built in the following process:

(1) Through the literature review, factors of environmental pollution and community-based environmental education are explored and the criteria required for the evaluation are confirmed;

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(2) The AHP principles are used to establish the hierarchy of each evaluation factor;
(3) The criteria extracted from the AHP questionnaire survey are ranked in a sequence of nine levels based on their relative importance;
(4) A consistency test is conducted on the returned questionnaires and only those questionnaire data with a consistency index of one or lower (C.I.≦1) and a consistency ratio of 0.1 or lower (C.R.≦0.1) are used in this study.
(5) The AHP formula is used to calculate the relative weight value of each evaluation factor; and
(6) Key factors of community-based environmental education can be found for one single community or multiple communities for their references in the evaluation of environmental education effectiveness.

Establishment of the criteria and hierarchy

In addition to conducting a literature review to explore and compile the factors, in-depth interviews with experts were also held to confirm the AHP criteria and hierarchy (see *Fig. 3*). According to the experts, the goal of environmental education based on the social and cultural characteristics of the community is to facilitate the realization of expected results and efficiency of policy advocacy and implementation through the close interactions, geographic proximity, common interests and information sharing of community residents. However, in addition to professional contents and educational methods, successful community-based environmental education also requires community residents' preference and recognition as well as sufficient funding. Therefore, according to the unanimous opinions of the experts, community-based environmental education in this study is first divided into three criteria for evaluation: advocacy method, community residents' attitude and sources of funding. These three criteria are the level-1 criteria in the framework. The criterion of advocacy method is further divided into three sub-criteria: teaching materials and contents, environmental protection activities and regular advocacy; community residents' attitude into four sub-criteria: perception of environmental protection, participation rate, proportion of volunteers and sustainable development of community; and finally sources of funding into four sub-criteria: residents' donation, enterprises' donation and government's subsidization. These ten sub-criteria are the level-2 criteria in the framework. The hierarchy of the overall assessment criteria is shown in *Fig. 3*.

AHP calculation of the weight value (Wi) of each criterion

The subjects in this study were 20 communities in Kaohsiung of Taiwan. Questionnaires were distributed by the assistant to board chairperson in each community (to community residents, schools, companies and other kinds of organizations in the community). The questionnaire survey was intended to find out the perceived importance or influence of each criterion for the community-based environmental education. Totally 90 questionnaires were given and 72 samples were returned with a return rate of 80%. Among the returned samples, 66 were valid. Based on the questionnaire results, the weight value of each criterion was calculated to measure its importance in the evaluation system. The calculation results are shown in the following *Table 1*.

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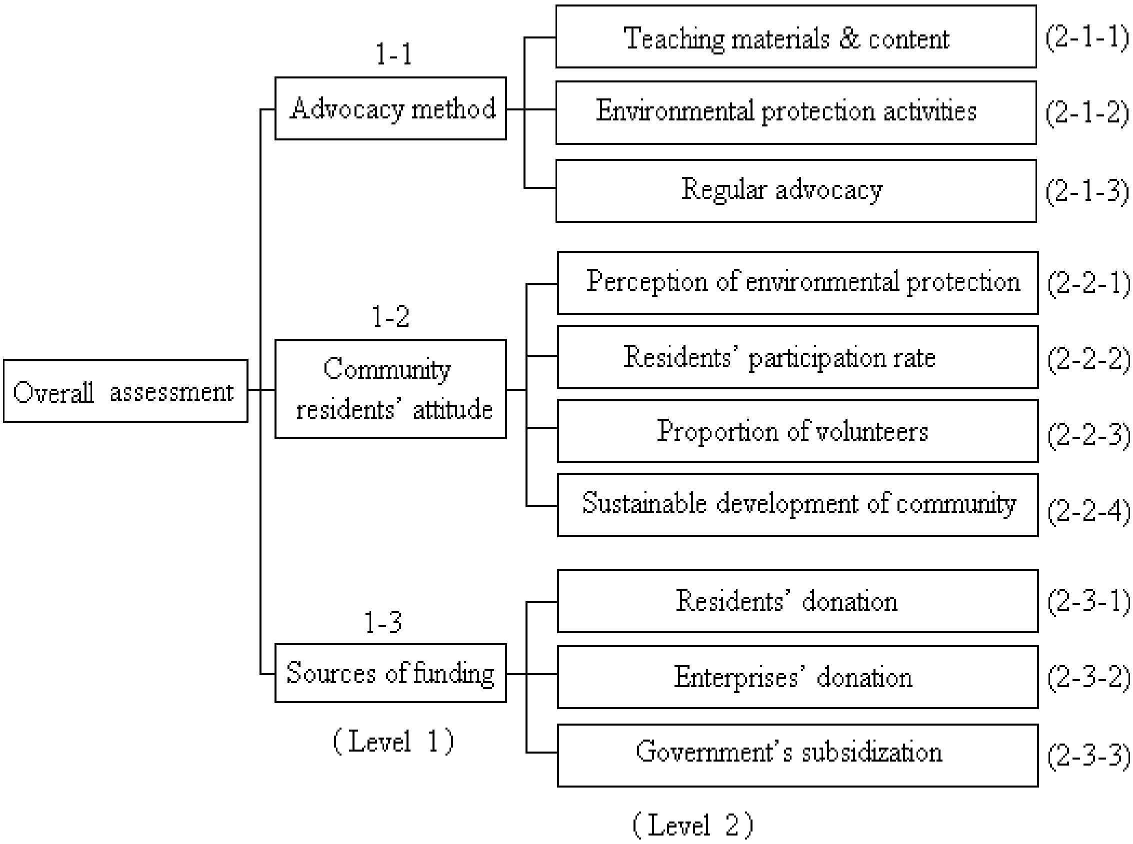

Figure 3. *Hierarchy of the evaluation criteria*

Table 1. *Weight value of each evaluation criterion for community-based environmental education*

Criterion	Level 1 (W_i)	Sub-criterion	Level 2 (W_i)	C.I.≦1 C.R.≦0.1	Overall *Wi*	Overall Sequence
1-1	0.312	2-1-1	0.287	C.I.=0.048 C.R.=0.083	0.090	8
		2-1-2	0.353		0.110	5
		2-1-3	0.360		0.112	4
1-2	0.394	2-2-1	0.236	C.I.=0.081 C.R.=0.090	0.093	7
		2-2-2	0.288		0.113	3
		2-2-3	0.270		0.106	6
		2-2-4	0.206		0.081	9
1-3	0.294	2-3-1	0.181	C.I.=0.010 C.R.=0.017	0.053	10
		2-3-2	0.430		0.123	1
		2-3-3	0.389		0.114	2
Overall *Wi*					0.995	

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Discussion of the weight value (Wi) of each criterion

According to the calculation results of the AHP questionnaire data, among the level-1 criteria, the most important is the criteria of community residents' attitude with a weight value of 0.394, followed by advocacy method (W_i=0.312) and sources of funding (W_i= 0.294). In addition, all the questionnaire results of the level-1 criteria pass the consistency test with C.I.=0.042 and C.R.=0.073. These findings indicate that, among the evaluation criteria of community-based environmental education, the most important one is the community residents' attitude.

All the questionnaire results of the level-2 criteria pass the consistency test and they are ranked in the following overall sequence according to their weight values: (1) enterprises' donation; (2) government's subsidization; (3) residents' participation rate; (4) regular advocacy; (5) environmental protection activities; (6) proportion of volunteers; (7) perception of environmental protection; (8) teaching materials and content; (9) sustainable development of community; and (10) residents' donation. Based on the ranking of the ten sub-criteria, it can be found that, to ensure better results of community-based environmental education, more focus should be placed on having environmental protection activities, obtaining enterprises' donations and governmental subsidies, and enhancing residents' participation and having regular advocacy activities. The overall AHP multi-criteria decision making model is illustrated in *Fig. 4*. The evaluation model established in this study can provide references for governmental authorities of environmental protection in their policy making process. The model can also be used to evaluate the implementation of community-based environmental education in multiple communities and select the community with best implementation results as an example to provide references for the subsidization of community-based environmental education. In addition, the model can also be used by a community to evaluate its own community-based environmental education, invest more in the key factors and consequently enhance the results and efficiency of the environmental education.

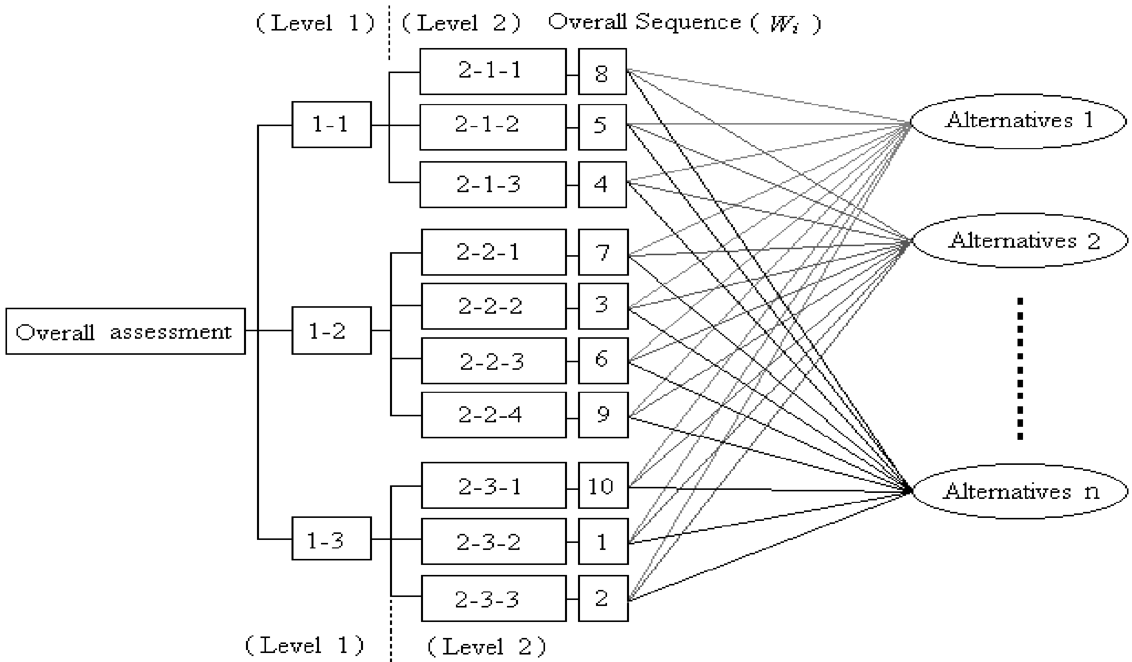

Figure 4. *Overall AHP multi-criteria decision making model*

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Fuzzy logic theory and modeling

As indicated in the research by Hsueh (2014), the fuzzy logic theory was developed by Zadeh in 1965. He proposed that the set of { 0, 1 } was no only composed of the two subsets of (0 and 1) and redefined the { 0, 1 } set as composed of indefinite subsets. The fuzzy logic theory can accept imprecise and ambiguous human semantics such as “like a lot”, “like”, “average”, “dislike” and “dislike a lot” (Hsueh, 2014). Therefore, the fuzzy logic theory is capable of computing with words (Zadeh, 1996). It is often used in the building of quantitative evaluation models. A fuzzy logic inference system (FLIS) is illustrated in *Fig. 5*.

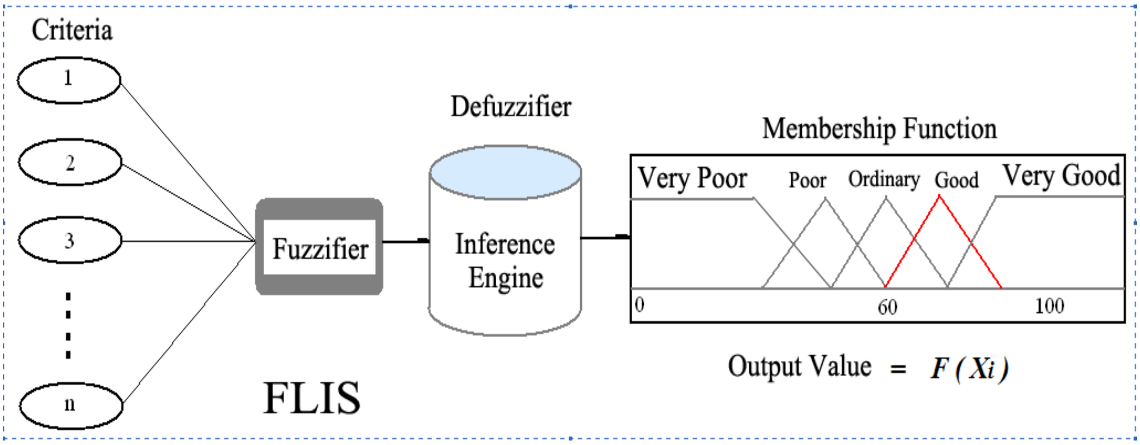

Figure 5. *Fuzzy logic inference system*

FLIS parameter definitions, inputs and outputs of level-1 criteria

In the evaluation of overall community-based environmental education results, only the quantified values ($f(x_i)$) of the level-1 criteria are needed for the calculation. As indicated in *Fig. 3* and *Table 1*, the three level-1 criteria are advocacy method, community residents’ attitude and sources of funding. In the modeling based on the fuzzy logic theory in this study, the membership function (MF), fuzzy sets and fuzzy ranges of the three criteria are defined (see *Table 2*). For the membership functions, Gauss-MF and Tri-MF, two types of frequently used membership functions, are applied in this study. The fuzzy range is often defined between 0-100. For the criteria of advocacy method, the fuzzy range is defined based on the number of methods to attract residents’ participation in the environmental education activities. With three fuzzy sets for each of the three criteria, there are totally 27 scenarios (3*3*3=27). As indicated in *Fig. 4*, the quantitative output ($f(x_i)$) of each scenario can be obtained through the FLIS calculation. *Fig. 6* is the 3D representation of the connections among all the inputs and outputs of the scenarios.

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Table 2. *Parameter definition of the fuzzy logic model*

Level 1 Criteria	Membership Function(MF)	Fuzzy Set	Fuzzy Range
Advocacy method	Gauss- MF Tri-MF	(Few, Average, Diverse)	0 – 20 Methods
Community residents' attitude	Gauss- MF Tri-MF	(Indifferent, Average, Enthusiastic)	0 – 100%
Sources of funding	Gauss- MF Tri-MF	(Few, Average, Many)	0 -100%
Quantitative Output	Tri-MF	(Very High, High, Average, Low, Very Low)	0 -100
Note	Gauss- MF and Tri- MF are two types of frequently used membership functions.		

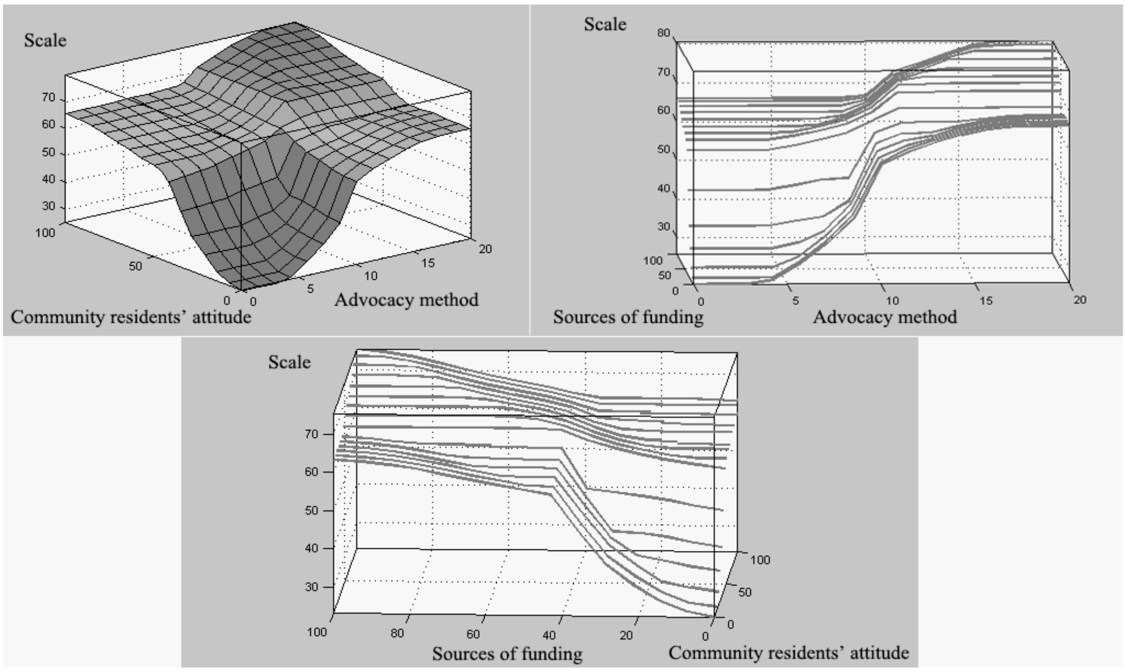

Figure 6. *Connections among inputs and outputs of level-1 criteria in different scenarios*

Model application and case analysis

The calculation formula of the multi-criteria model established in this study is:

$$\sum_{i=1}^{n}\left(f(x_i)\times W_i\right)$$

There are three steps in the application of this model: (1) obtaining the quantitative

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outputs (*$f(x_i)$*) through FLIS; (2) calculating the relative weight value of each evaluation factor (W_i); and (3) quantitative evaluation of the scenario or the case ($f(x_i)*W_i$).

The case analysis of the best, average and worst scenarios in this study is shown in *Table 3*. The quantitative outputs of each scenario can be calculated using either the membership function formulas proposed by Zadeh, computer programming languages or FLIS established by MATAB software. The use of MATAB to establish a multi-criteria fuzzy logic evaluation model is more about the settings of the fuzzy inference system, fuzzy rules, membership functions and fuzzy operators than the software itself. Through the FLIS calculation, the quantitative outputs of the best, average and worst scenarios are respectively 91.4, 66.3 and 21.8 and the influence of each criterion in the three scenarios are also quantified (see *Table 3*).

Table 3. *Case analysis of the best, average and worst scenarios*

Criterion	W_i	Best Case $f(x_i)$		Average Case $f(x_i)$		Worst Case $f(x_i)$	
		$f(x_i)$	$f(x_i)*W_i$	$f(x_i)$	$f(x_i)*W_i$	$f(x_i)$	$f(x_i)*W_i$
Advocacy method	0.312	91.4	28.52	66.3	20.69	21.8	6.80
Community residents' attitude	0.394		36.01		26.12		8.59
Sources of funding	0.294		26.87		19.49		6.41

Conclusion

It is found in this study that the factors of significant influence for community-based environment education advocacy and implementation are sources of funding (enterprises' donation and government's subsidization), participation of community residents, number of participants, and activity contents. Therefore, for community-based environmental education, it is important to first attract participation of community residents with interesting activities and then promote awareness of the importance of environmental protection among the participating residents through the activity contents. It is suggested classroom-like lecturing and presentation should be reduced in the education to boost the willingness of community residents to participate. Such kind of activity-oriented education can be costly; therefore, governmental subsidies and enterprises' donations can be very helpful. To conclude, sustainable and successful community-based environmental education depends on sufficient volunteers of the community development association, attractive activities and contents for local community residents, enthusiastic participation of community residents, regular advocacy and sufficient funding. Moreover, the multi-criteria quantitative evaluation model established in this study is highly objective. It can be used by a community to evaluate the development of its environmental education and by governmental authorities to evaluate the results of environmental education policy advocacy and implementation in one or multiple communities.

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