

# EFFECT OF CITIZEN ACTION ON SUPPRESSION OF INVASIVE ALIEN LIZARD POPULATION: A CASE OF THE REMOVAL OF *EUTROPIS MULTIFASCIATA* ON GREEN ISLAND, TAIWAN

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** This paper analyzes data from the 2009-2016 projects for the removal of the invasive alien species *Eutropis multifasciata* from Green Island, Taiwan. In this study, the perimeter trapping method was used, and the validity of the method was verified at the beginning of the study. The result showed that the exponential regression analysis showed a statistically significant negative relationship between capture rate and time. Thus perimeter trapping was indeed an effective way of removing *E. multifasciata*. Besides, it investigates whether citizen action can assist in the removal of invasive alien species. The process of removal occurred in two stages; the first was funded by government, and the second involved citizen action. When citizens took over the work of removal, the size of the animals removed continued to decrease, as did the ratio of alien to indigenous individuals captured. In this case, introducing citizen action was an effective method of removing this invasive alien species.

**Keywords:** *exponential decay model, eradication, civic ecology, community participation, volunteer tourism*

## Introduction

With the current changing environment, the effects of humans on the environment have become increasingly frequent, and the threat of invasive alien species (IAS) has become an important problem in the conservation of biodiversity (Bonanno, 2016). Past studies have found that IAS are one of the main reasons that species go extinct, second only to the destruction of habitats (Canadell and Mooney, 2002; Sharma and Raghubanshi, 2011; Wilcove et al., 1998). Furthermore, an island environment is more threatened by IAS than a mainland environment (Glen et al., 2013; Towns et al., 2013). In the last 500 years, three quarters of vertebrate extinctions and two thirds of plant extinctions have occurred on islands, and the primary factor in these extinctions has been the effect of IAS (Sax and Gaines, 2008). For example, in New Zealand, 70% of the mammals, 95% of the birds, and 90% of the reptiles have gone extinct (Keitt et al., 2011). Thus IAS can have a major effect on biodiversity in fragile island ecosystems. Moreover, Yiming et al. (2006) believes that since small islands have a lower biological resistance against IAS, IAS can easily establish a functional group and begin to spread.

Located on the western rim of the Pacific Ocean, Green Island is only 17 km<sup>2</sup> in area. Human life was already present there 4000 years ago (Chan, 2009), but since the

primary economic activity on the island changed from farming and fishing to tourism in the nineties, the frequent visits by tourists have increased the chances of alien species invading Green Island. The nineties of the 20<sup>th</sup> century, past studies have shown that regardless of climatic zone, human travel is the primary method by which alien species are introduced (Anderson et al., 2015; Koutika et al., 2011). The common sun skink (the scincid *Eutropis multifasciata*, Kuhl 1820) was first discovered on Green Island in 2008, and is believed to have been introduced to the island via tourism (Chen et al., 2008).

*E. multifasciata* originates from Indochina and southeastern Asia (Uetz and Hošek, 2016). It was first found to have invaded the Kaohsiung region of Taiwan in 1992 (Ota et al., 1994), and presently occupies low altitude habitats in southwestern Taiwan. As *E. multifasciata* adapts easily to the environment, and preys on other lizards in its habitat, the populations of indigenous lizards in that area have declined sharply. The invasion of *E. multifasciata* on Green Island has received attention because it preys on the endemic species the scincid *Plestiodon chinensis leucostictus* and other indigenous lizards, threatening the island's biodiversity (Chao et al., 2009).

Simberloff (2009) has identified five factors crucial to the successful eradication of IAS: (1) swift action in the early stages of invasion; (2) the allocation of adequate resources to complete the project; (3) the cooperation of stakeholders with the institution responsible for the eradication; (4) adequate research into the background of the target species; and (5) energy, optimism, and persistence in the project leaders when facing occasional difficulties. Of these five factors, the greatest difficulty in this case is limited finances and human resources, which creates challenges in identifying an appropriate course of action to eradicate or suppress *E. multifasciata*. The removal of *E. multifasciata* from Green Island initially received a lot of attention from the government, and four years of financial support, but the funding provided was rather low relative to the generally high cost of IAS eradication operations. For example, California successfully eradicated the invasive Pacific alga *Caulerpa taxifolia* in two years, but this cost 7,000,000 USD (Simberloff et al., 2013). Such enormous expenditures are a severe challenge for Taiwan and many other countries around the globe. Past studies have shown that introducing a moderate level of citizen action, such as enlisting communities or volunteers help with the work, is a feasible approach to this problem (Dolan et al., 2015; Glen et al., 2013; Harvey et al., 2016; Kelehear et al., 2012; Moon et al., 2015). However, the specific mode of operation of citizen action will vary according to the characteristics of the community, so identifying the method that will result in the specific outcomes required is a key issue in the removal of IAS.

Cromarty et al. (2002) identified the following core principles for the removal of island IAS: (1) the method of removal must be feasible; (2) the rate of removal must be higher than that of population growth; and (3) there must be no new invaders. These principles have provided specific methods for removing IAS.

In this study we analyze data from the 2009-2016 removal of the IAS *Eutropis multifasciata*, with two primary investigative purposes. Firstly, we seek to investigate whether perimeter trapping, the initial method of capture, was effective in removing *E. multifasciata*. Secondly, we discuss whether introducing citizen action is sufficient to suppress *E. multifasciata* and stimulate the recovery of native lizards, since the government is unable to keep funding the removal. Because lizards do not usually pose an immediate hazard to humans or the environment, it is difficult to obtain

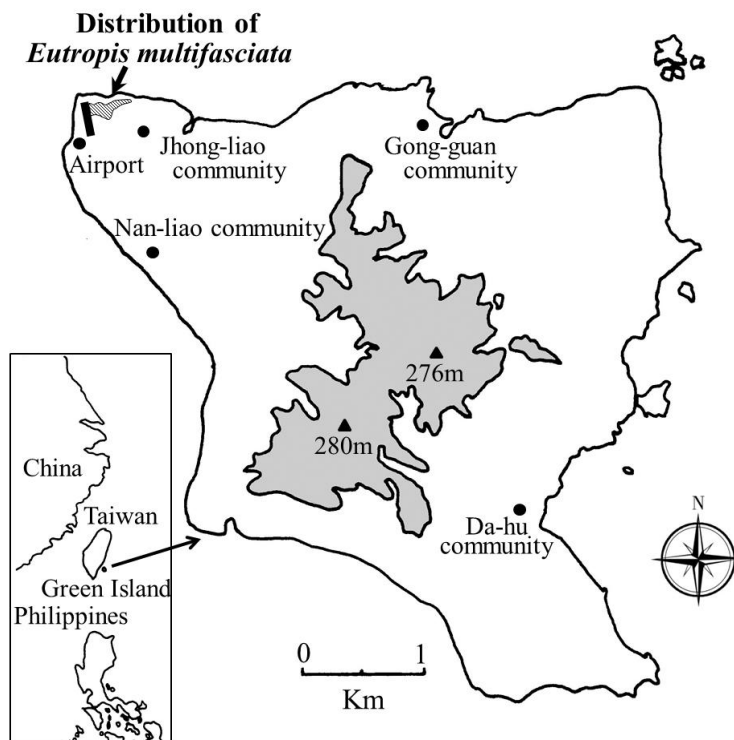
resources for removing invasive lizards from IAS-eradication funding. There are thus few cases of successful eradication of invasive lizards. This study can provide a reference for such cases in future.

## Materials and methods

### Study area

Green Island is located on the western rim of the Pacific Ocean, off the southeastern coast of Taiwan (22° 38.40' to 22°41.16' N; 121°27.15' to 121°31.20' E). The island's area is approximately 1700 ha. Presently, *E. multifasciata* mainly occupies the northwestern corner of the island, covering an area of 10 ha (including potentially occupied areas of the invasive species; Fig. 1).

Green Island has a subtropical monsoon climate. It is warm, humid, and windy all year. The average annual temperature is 23.5 °C. There is mean annual rainfall is 2500 mm and there is no significant dry season. Prior to 1990, the inhabitants supported themselves by farming and fishing. However, since the enactment of government policy changes in 1990, Green Island has developed a tourism industry. The island has a population of 3,000, but receives 300 000 visitors per year. This change did not only affect the island's economy, but also had a range of social and ecological effects (Chao, 2014a). Since tourism is presently Green Island's primary industry, it was suggested that the *E. multifasciata* eradication work could be integrated with the tourism industry. In this way, volunteer trips would be used to introduce off-island volunteers to helping to remove IAS, in addition to involving volunteers from the community.



**Figure 1.** Distribution of *Eutropis multifasciata* on Green Island. The island's northwest corner (slanted line) is its primary range, which covers approximately 10 ha (including potentially occupied areas of the invasive species)

### **Data collection**

The period over which this study's data were collected is divided into two stages. The first stage, 2009-2012, was supported by government funding. From July 2009 to February 2010, perimeter trapping was used, mimicking that used for the removal of the invasive snakes (*Boiga irregularis*) on the Pacific island of Guam (Engeman and Vice, 2001; Engeman et al., 2000). But with the different of them, this study did not use any bait in our tarps. So that the traps were cost-effective and easily transportable, materials such as bamboo sticks, construction tape, and shrimp cages were used to construct 100 funnel traps, which were set around the perimeter of the forest. The traps were checked twice daily, at dawn and at dusk, to check that this trapping method was appropriate and to remove any animals caught. The indigenous lizards were be released immediately, but the *E. multifasciata* were be eradicated and took back to laboratory. Later March 2010 onwards, to improve the results, the construction tape was replaced with PP plastic boards. The boards were used to construct complete fences around the areas where the *E. multifasciata* had been found, and otherwise the methods remained unchanged. In addition, however, to assess the effect of the mass removal on the growth of the lizards, the snout-vent length (SVL) of each individual captured was measured.

The second stage, 2013-2016, was after the government had ceased subsidizing the project. The work of removing *E. multifasciata* was then done by the community and volunteer tourists. The first stage had been primarily conducted by researchers, but to compensate for the predicted cessation of funding, the community was encouraged to participate. In 2012, environmental education for the community was commenced, and interested volunteers from the community were recruited to learn the process, including species identification and removal methods. In 2013, then, these community volunteers took over the work of eradication. The methods used were the same as in the first stage, but community volunteers were limited. Although *E. multifasciata* is active throughout the year, indigenous lizards are most active from May to October (Chao et al., 2009), which coincides with the tourist season on Green Island, and the effort spent on the removal by local volunteers decreased as a result. The process was therefore designed to be a travel activity for tourists as well, and marketing mechanisms were used to bring in off-island volunteers to assist in the removal process.

All captured and removed *E. multifasciata* will be brought back to the laboratory, and to be measure the external morphology, including SVL, weight, gender etc. We dissected the contents of the stomach and checked the reproductive gland development, to determine whether the individual sexual maturity. Individual sexual maturity is judged on the basis of Auffenberg and Troy (1989) findings. They considered the individual, which the yolking ovarian follicles > 3 mm in ovaries, or oviductal eggs developing, was recorded as adult female. And the individual, which the seminiferous tubules were found to developed mature spermatozoa in the tissue sections of the testes, was recorded as adult male.

The capturing process is approved by the competent authority of the East Coast National Scenic Area Administration. We captured the *E. multifasciata* sent to the Endemic Species Research Institute to do research of permanent preservation. The indigenous lizards we captured were released in situ after recording the morphological data.

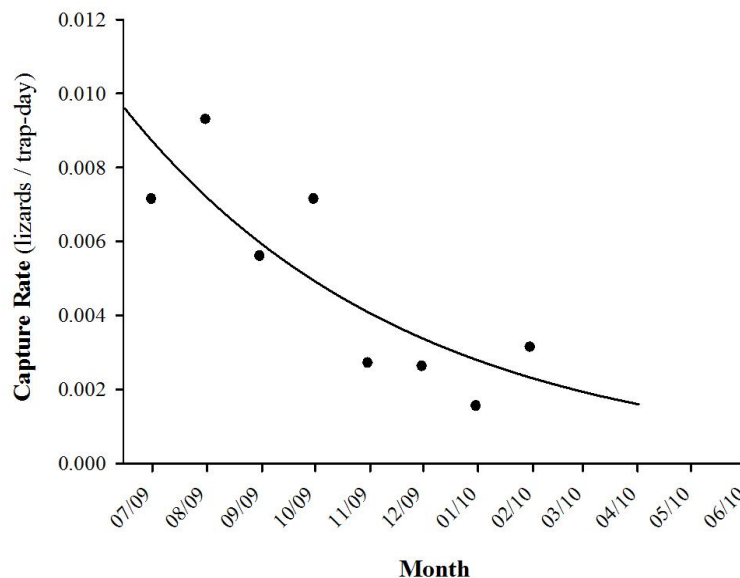
## Data analysis

Engeman et al. (2000) believed that an appropriate removal method would cause the capture rate to follow an exponential decay model. To assess whether the first-stage method (perimeter trapping) was successful, the capture rate was tested using exponential regression. And capture rate refers to lizards trapped divided by total trap-days. Later on, the change in SVL over time and the capture rate over time was analyzed using one way ANOVA and linear regression. The analysis was performed using SPSS 19 software.

## Results

### Testing the results of perimeter trapping: exponential decay model

To check that perimeter trapping was an effective method of removing *E. multifasciata*, data were collected for eight months, starting in July 2009. During this period, 349 animals were captured, of which 137 were juveniles (SVL:  $52.75 \pm 1.06$  mm), 120 were males (SVL:  $91.35 \pm 0.88$  mm), and 92 were females (SVL:  $91.62 \pm 0.93$  mm). The exponential regression analysis showed a statistically significant negative relationship between capture rate and time ( $R^2 = 0.695$ ,  $p < 0.01$ ), and the regression curve fit the exponential decay model with the following equation: capture rate =  $0.0105^* \exp(-0.1909^* \text{month})$  (Fig. 2). Thus perimeter trapping was indeed an effective way of removing *E. multifasciata*.



**Figure 2.** Change in capture rate of *Eutropis multifasciata* on Green Island when using perimeter trapping in 2009 and 2010. The capture rate fit the exponential decay model ( $R^2 = 0.695$ ,  $p < 0.01$ ).

In 2011, since the project was receiving funding from the government, effort was increased from 100 to 300 traps a day, to eradicate more IAS. As expected, the number of indigenous lizards trapped increased with the number of traps. This showed that the effectiveness of the perimeter trapping had not decreased over time (the lizards had not

simply learned to avoid the traps). The capture rate of *E. multifasciata* continued to decline steadily, however, so its abundance was indeed decreasing as a result of the trapping.

Although the project was still receiving government funding in 2012, the amount of funding had decreased dramatically, suggesting that the government might cease to provide funding in the near to immediate future. A plan was therefore made for community volunteers to take over the task of controlling the *E. multifasciata* population. Since the lizards are most active in summer, which coincides with the tourist season on Green Island, the amount of time the volunteers could spend on the removal project was going to be limited. To decrease their workload, the amount of time spent on the project was cut in half (to 15 days a month, in the other 15 days the traps were to be removed and when volunteers could join the traps would be set up again), although the number of traps remained at 300. This was not ideal, since *E. multifasciata* would not be as tightly controlled, and the population might increase again (Table 1). Clearly, if using citizen participation to remove IAS, there would need to be an adequate number of volunteers. Since the numbers of community volunteers were insufficient, off-island volunteers were introduced. However, the people on Taiwan view Green Island as a far-off rural area, and convincing off-island volunteers to stay long-term was not going to be easy. Therefore, after considering the characteristics of the economy of the island, it was decided in 2013 that the removal project would be integrated into the tourism industry, creating a volunteer travel activity that would revolve around environmental education, to fill the volunteer deficit. In 2013, with the added human resources of the off-island volunteers, the number of traps was decreased to 200 and the trapping frequency reverted to daily.

**Table 1.** Number of removed *Eutropis multifasciata* on Green Island, 2010-2015 (including only data from March to October, when the lizards were most active)

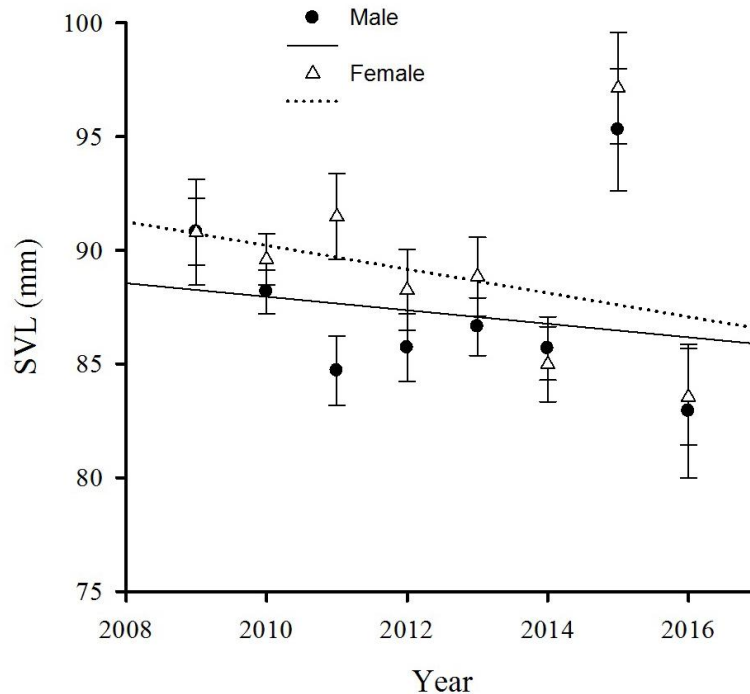
Removal information	Government funding stage			Citizen participation stage		
	2010	2011	2012	2013	2014	2015
Total effort (trap-days)	36,750	73,500	36,750	49,000	49,000	49,000
No. indigenous lizards trapped	626	1,542	490	726	976	1,001
Capture rate of indigenous lizards per 100 trap-days	1.70	2.10	1.33	1.48	1.99	2.04
No. of <i>E. multifasciata</i> removed	282	237	76	169	115	55
Ratio of <i>E. multifasciata</i> to total lizards trapped (%)	<b>31.1</b>	<b>13.3</b>	<b>13.4</b>	<b>18.8</b>	<b>10.5</b>	<b>5.2</b>

### **Analyzing the benefits of using community volunteers and volunteer tourism to assist with the removal of *E. multifasciata***

#### *Change in Snout-vent length (SVL) over time*

From 2009-2016, the size of adult *E. multifasciata* decreased gradually (males:  $R^2 = 2.543$ ,  $p < 0.001$ ; females:  $R^2 = 6.712$ ,  $p < 0.05$ ) (Fig. 3). Although the individuals captured in 2015 were larger, the lizards captured the next year were smaller than those caught in 2014. Overall, regardless of sex, the size of adult *E. multifasciata* decreased

with the mass removal of individuals from the population. This shows that because of the mass removal, *E. multifasciata* reached sexual maturity earlier, and their bodies thus became smaller. When community volunteers and volunteer tourists took over the removal work after government funding ceased in 2013, the SVL of mature male and female *E. multifasciata* continued to decrease, proving that citizen action can indeed suppress the population of this species.



**Figure 3.** Change in mean annual snout-vent length (SVL) of mature male (closed circles, solid line;  $p < 0.001$ ) and female (open triangles, dotted line;  $p < 0.05$ ) *E. multifasciata* on Green Island from 2009-2016.

#### Recovery of native lizards

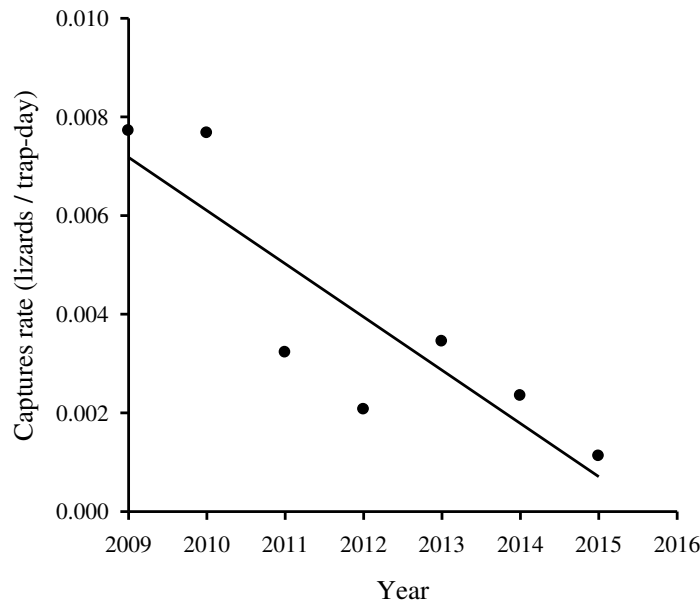
The capture rate of *E. multifasciata* per trap over the years 2009-2015 decreased according to a strong ( $R^2 = 0.759$ ) and statistically significant ( $p < 0.05$ ) linear relationship: capture rate (no. lizards/trap-day) =  $2.175 - (0.00108 * \text{year})$  (Fig. 4). Moreover, the proportion of *E. multifasciata* to total lizards trapped decreased from 31.1% in 2009 to 5.2% in 2015 (Table 1). This shows that when *E. multifasciata* was suppressed, recovery of the indigenous lizard populations can be assisted.

## Discussion

### *The importance of checking the stage of invasion by E. multifasciata*

Past studies have shown that IAS eradication is least costly and most likely to succeed in the early stages of the invasion (Carrion et al., 2011; Simberloff, 2003; 2009; Simberloff et al., 2013). An IAS invasion involves four stages: introduction, establishment, naturalization and spread/dispersal, and damage creation (Marbuah et al., 2014). Unless the IAS were intentionally introduced (e.g. for aquaculture, horticulture,

or as pets), they are usually discovered between the first and second stages, although sometimes not until the third stage. However, if the IAS does not pose an immediate threat, policy-makers have to be convinced to devote resources to removing it (Burbidge, 2011). In the case of *E. multifasciata*, the government was persuaded to provide resources for its removal by proof that the invasion was still in its early stages, and the population was thus successfully suppressed.



**Figure 4.** Average annual capture rate of *E. multifasciata* on Green Island from 2009-2015 ( $R^2 = 0.759$ ,  $p < 0.05$ )

As to the means by which *E. multifasciata* arrived on Green Island, Wiles (2000) reported that this species was found in luggage on a plane travelling from the Philippines to Guam, when the plane arrived at Guam airport. The population of *E. multifasciata* on Green Island is located close to the airport runway, and since the island has a well-developed tourism industry, it is thought that the lizards arrived via tourist traffic.

However, how did we know that the species was in the early stages of its invasion when it was discovered in 2008? This question is important, for when IAS have become widespread, the funding required for their removal increases greatly, and the removal effort is less likely to succeed (Simberloff, 2009), which makes the government less likely to provide funding for the project. The reason why there is no such project for *E. multifasciata* on mainland Taiwan is that it has already become too widespread there, and it would be difficult to curb its further spread. To assess the stage of the invasion, it is necessary to assess two aspects of the population. First, the female: male ratio should be investigated. In the 2009 survey, this ratio on Green Island was 1: 2.18 (Chao et al., 2009). In contrast, the ratio on mainland Taiwan was 1: 12 (Chen and Lin, 2003). A reason for this difference might be that the group of *E. multifasciata* on Green Island was still in the early stages of invasion, and its sex ratio had therefore not yet stabilized. Secondly, the entirety of the area available to the IAS should be surveyed to find out where the invasive species is. *E. multifasciata* was found to occupy about 4 ha of the northwestern corner of Green Island, close to the airport. The potential area available to



it (according to habitat suitability) is 10 ha (Chao et al., 2009). From these two findings, it was determined that *E. multifasciata* was still in the early stages of its invasion on Green Island.

### ***The contribution of scientific knowledge to the removal of E. multifasciata***

From a purely scientific viewpoint, the first thing to do in IAS removal is to ensure that the method used is feasible (Russell and Holmes, 2015; Towns et al., 2013). Engeman et al. (2000) believed that an effective removal method would result in an exponential decay model of the IAS capture rate, because over time an increasing proportion of the original population would have been removed. The removal effort on Green Island used perimeter trapping with funnel traps to remove *E. multifasciata*, and the curve of the capture rate fit an exponential decay model (Fig. 2), showing that this method was indeed effective. Although the amount of effort expended was later adjusted, the same capture method was still used, and the removal effort continued to succeed.

The contributions of scientific knowledge to this project include not only the assessment of the removal method, but more importantly, the education of the public and stimulation of citizen participation. Glen et al. (2013) believes that IAS removal on inhabited islands is even more important than on uninhabited islands, but also more difficult, because it is a challenge to get support from the inhabitants. Many island inhabitants do not understand the importance of IAS and the problems they cause, and this results in resistance during the removal process, which becomes the primary reason the removal fails (Moon et al., 2015). For example, during the *E. multifasciata* removal project on Green Island, most inhabitants could not tell the difference between the alien lizards and *P. chinensis leucostictus*, a subspecies endemic to Green Island, and initially believed that the project was damaging the environment by capturing *P. chinensis leucostictus*. Simberloff et al. (2013) stated that scientists have a duty to educate the public about IAS and resolve any misconceptions or doubts they have about them. In 2012, therefore, environmental education was provided through the school and the community, and as a result volunteers were recruited, which opened up the possibility of further citizen action in 2013.

### ***Evaluating the effects of removing E. multifasciata***

IAS removal is important, challenging work with ecological implications, and since it emphasizes effectively suppressing or eradicating IAS populations, assessing the effects of the removal effort is important. Evaluating the success of the project can be done in two ways. First, the size of the organisms can be measured. Hutchings (2004) compared the sizes of Atlantic cod captured in the sixties and the nineties, and found that because of overfishing (removal), the size of the fish had decreased significantly. This may have been the result of rapid evolution of the eggs, which may have increased in quantity but decreased in size when the population had decreased rapidly, and led to smaller fry (Heath et al., 2003). Although we have not analyzed the clutch size of *E. multifasciata* on Green Island, the effects of the removal project can be seen in the reduction in length of adults of both sexes (Fig. 3). From this we conclude that the removal method effectively suppressed the population of *E. multifasciata*.

Secondly, the success of the project can also be evaluated by assessing the recovery of the original ecosystem; after all, this is the desired end-result of a removal project.

From the decreasing capture rate of *E. multifasciata* on Green Island (Fig. 4), we can see that the population was successfully suppressed. Moreover, the change in percentage of *E. multifasciata* of all lizards trapped (Table 1) dropped from 30% in 2009 to about 5% in 2016. This shows that the removal mechanism used did indeed suppress the population of *E. multifasciata*, and recovery of the indigenous lizard populations can be assisted (the capture rate of native lizards increased from 1.7 to 2.14, Table 1).

### ***The value and operating mechanisms of citizen action in the removal of E. multifasciata***

In recent years, increasing numbers of studies have shown that citizen action has a positive effect on the removal of IAS (Dolan et al., 2015; Glen et al., 2013; Harvey et al., 2016). When considering the complications of removing IAS and the problems with obtaining the financial resources required for long-term monitoring, Simberloff (2009) suggested adding volunteer participation to plans for removing and managing IAS. There are many benefits to citizen participation in the removal of IAS, as can be seen from operations such as the project to remove Amur bush honeysuckle (*Lonicera maackii*) in Indiana, USA. Even if there are no actual benefits with respect to the success of the project, the volunteers learn about the effects of IAS; in other words, they receive environmental education through participation, as in the case of the removal of Burmese pythons (*Python bivittatus*) in Florida, USA (Harvey et al., 2016). Irrespective of the type of benefits seen, the participation of citizens contributes to the area's sustainability. Krasny and Tidball (2012) termed this type of citizen action "civic ecology", and suggested that these actions are "self-organized" by members of the community following a period of environmental and social deterioration. The problem is how to stimulate the participation of community members; is there any particular mechanism for encouraging community members to participate in IAS removal work? These are key issues in the process of this type of citizen action.

Regarding this question, Chao (2014b) proposed a conceptual framework for a "local intermediary organization", suggesting that when trying to encourage community participation, there must be a local organization that helps to uncover and solve social problems, introduce resources, and stimulate development. Chao (2015a) explained that for small, remote communities, the role of local intermediary organizations was even more important, since they could stimulate innovation in the community, reinvigorate the strength of the social force, and make long-term commitments to community sustainability. Simberloff (2009) has pointed out that one of the features needed for IAS removal to succeed is an optimistic and dedicated leader. This view is slightly amended in the conceptual framework in Chao (2014b), elevating the role of stimulating removal work from an individual to "institutions and organizations", since most IAS removal projects and the management thereof are lengthy and time consuming. Follow-up administration and monitoring is also crucial. With a local organization to shoulder this work, the removal and management of IAS can be sustained. To return to the case of the removal of *E. multifasciata* on Green Island: the organization that encouraged the community to participate was a local intermediary organization, The Society for Nature and Humanity. Since this organization had long been involved in community work on Green Island, they had won the inhabitants' approval, and could swiftly recruit local volunteers to participate in the removal project.

Green Island is a tiny island with a population of 3000, and the amount of work community volunteers are able to contribute is limited, which is reflected in the results from 2013 (*Table 1*). Past research has found that using ecotourism to remove IAS and create economic benefits is a good management method for inhabited islands (Ogden and Gilbert, 2011; Samways et al., 2010). IAS removal work does not require a lot of technical knowledge, but does require a large workforce (Simberloff, 2009). For example, in this case, setting up and checking traps does not require a lot of knowledge, but even though it seems dull and repetitive, it is suitable as an activity for a volunteer trip (Chao, 2014a), and will attract volunteers. Moreover, volunteer trips are a form of sustainable travel (Dorin-Paul, 2013), which fits into Green Island's goal of sustainability. With the help of local intermediary organizations, the training of community volunteers, and marketing campaigns, Green Island has succeeded in attracting off-island tourists to help with the *E. multifasciata* removal work on themed trips. Currently, Green Island has over 3000 people participating in these trips each year (Chao, 2015b). The volunteer trips have not only succeeded in solving the labor problem the program faced after the government funding ceased, but has also brought economic benefits to community volunteers and encouraged them to keep participating.

Completely eradicating IAS is very difficult, but Simberloff (2003) suggests that, from a maintenance and management point of view, keeping IAS in an acceptable low-density state is sufficient. *E. multifasciata* on Green Island has not yet been eradicated, but the population is at a low density. Although the project received government funding in the beginning, the involvement of volunteers in the later stages of the project has been vital to its success. This mechanism will continue to play an important role in the follow-up monitoring and maintenance of *E. multifasciata* on Green Island.

**Acknowledgements.** This work first needs to thank the COA (Council of Agriculture) for its financial support. More importantly, many community volunteers, including staff of the Society for Nature and Humanity, and volunteer tourists to help, we were able to suppress the invasion species of Green Island.

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# IMPROVING AIR QUALITY IN COMMUNITIES BY USING A MULTICRITERIA DECISION-MAKING MODEL BASED ON BIG DATA: A CRITICAL REVIEW

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** Information technology has advanced rapidly and has long been used in various fields and industries. The accumulated data are valuable in practical applications related to topics, such as scientific research, commercial development, and policy-making references. Recent global climate anomalies are due to the ongoing reclamation and extensive use of natural resources in the ongoing process of human evolution and development. Demand for industrial development and economic competition among countries have caused high CO<sub>2</sub> emissions, which is becoming a severe problem. Through analyzing relevant big data, people can explore the causes of high CO<sub>2</sub> emissions and propose effective solutions. Factors contributing to high CO<sub>2</sub> emissions not only include the strong dependence on energy and its use in economic, industrial, and commercial development, but families and individuals also contribute to air pollution. To solve this problem, this study investigated topics on public policy issues involving big data, community education effectiveness, and low-interest loans. In addition, this study adopted the Delphi method, analytical hierarchy process, and fuzzy logic theory to establish a multicriteria decision-making model based on big data to evaluate the processes of reducing air pollution in urban areas. Because community education contributes to resolving public policy problems, the proposed MCDM model enables researchers to determine improvements in urban air quality and aids in discerning the effects of community education on the promotion of environmental protection policies. In addition, this study proposed methods involving grants and low-interest financing to enhance improvements.

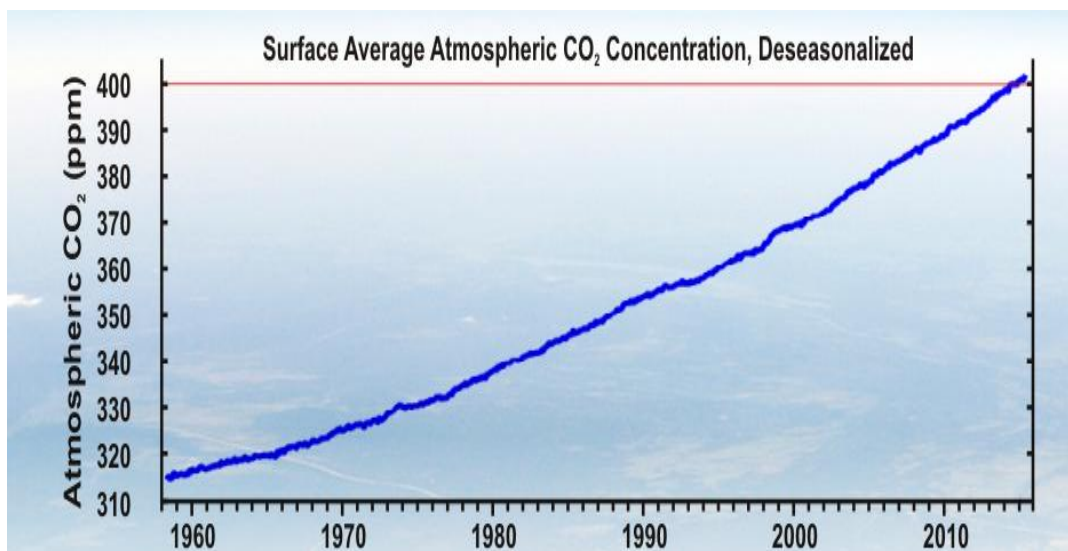
**Keywords:** *carbon dioxide, public policy issues, Delphi method, AHP, Fuzzy logic theory, community education*

## List of abbreviations

AHP	analytical hierarchy process
APEC	Asia–Pacific Economic Cooperation
CDIAC	Carbon Dioxide Information Analysis Center
CEO	chief executive officer
CI	consistency index
CO <sub>2</sub>	carbon dioxide
CR	consistency ratio
DFuzzy	Delphi - fuzzy logic theory
DAHP	Delphi - analytical hierarchy process
FLIS	fuzzy logic inference system
LED	light-emitting diode
MCDM	multi-criteria decision making

## Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992, and the related Kyoto Protocol was signed in 1997. However, total global CO<sub>2</sub> emissions not only remain high, but have exhibited an increasing trend annually. CO<sub>2</sub> concentrations in the atmosphere have increased from 310 ppm in 1960 to over 400 ppm as of 2015 (*Fig. 1*). After paying considerable attention to the problem of CO<sub>2</sub> emissions, European countries have achieved a considerable decrease in emissions each year, as has the United States in recent years. In other countries, however, CO<sub>2</sub> emissions continue to rise, particularly in China and India, where the economies are growing rapidly. *Figure 2* depicts the CO<sub>2</sub> emissions in China and other major countries (Liu, 2015). Whether atmospheric CO<sub>2</sub> concentrations can be reduced to less than 300 ppm, as it was before 1960, depends on every country's effort in effectively reducing the use of gasoline, coal, and natural gas. Concurrently, it also depends on the development of low-carbon clean energies to mitigate the steadily increasing atmospheric CO<sub>2</sub> concentrations.

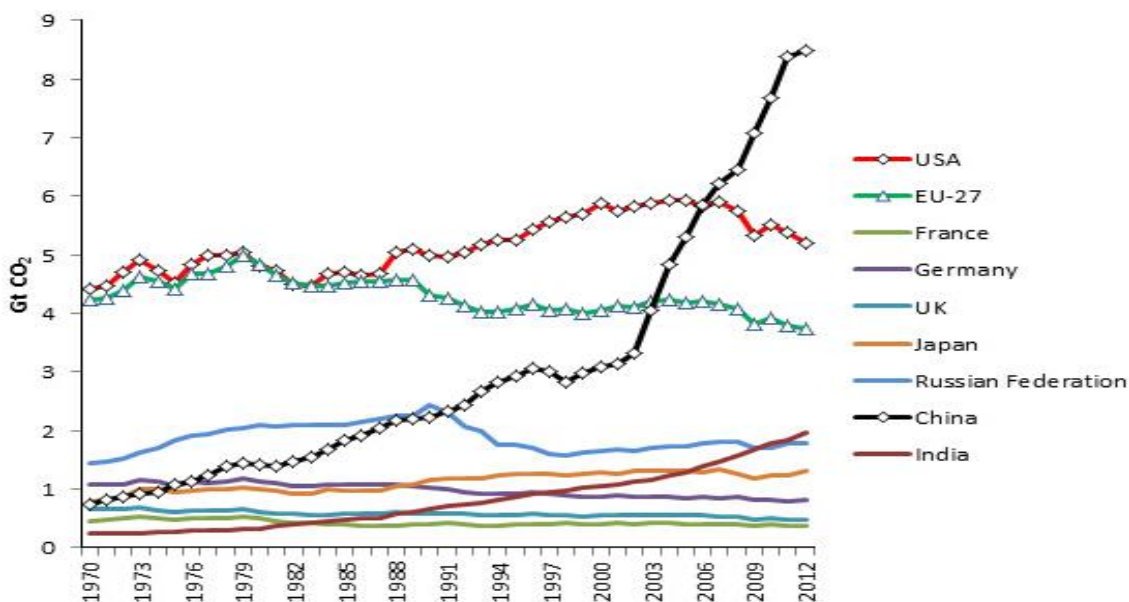


*Figure 1.* The atmospheric CO<sub>2</sub> concentration during 1960-2015 (CDIAC, 2015)

The government of China reduced the environmental pollution during the Beijing APEC Summit in 2014 and on the China Victory Day parade in Beijing on September 3, 2015. These events indicate that CO<sub>2</sub> emissions can be reduced through effective policy measures, but such efforts would require support from most people. Furthermore, enterprises must be willing to sacrifice their interests, and governments must be committed to the long-term execution of policies aimed at reducing environmental pollution and CO<sub>2</sub> emissions.

In recent years, information technology has been integrated into the economy and society, triggering a rapid increase in data, which have consequently become the basis of China's strategic resource (State Council of the People's Republic of China, 2015). China is currently promoting applications for big data in order to stimulate economic development and promote environmental protection. Big data on energy has the

following characteristics: high volume, wide variety, high velocity, energy, exchange, and empathy. These features not only facilitate constructing a core value chain of the Internet of energy, but also assist in optimizing the overall system and in meeting individual needs (China Report Hall, 2015). Big data could offer valuable information for practical scientific research applications, industrial and commercial development, national economic development, and issues of global concern.



*Figure 2. The CO<sub>2</sub> emissions of major countries during 1970-2012*

Moreover, the effectiveness of resolving public policy problems depends on the assistance and cooperation of citizens. Thus, community education can effectively aid the public sector in promoting policies. In recent years, the high CO<sub>2</sub> emissions from excessive energy consumption by humans have resulted in air pollution, the greenhouse effect, global warming, climate change, and severe environmental pollution, which endangers biodiversity and human life and property. The problem of high CO<sub>2</sub> emissions must be addressed and improved to prevent further deterioration of the global environment and catastrophic crises. An urban environment consists of diversified communities that form the basic units of local fundamental construction. However, communities are also the collective hub of energy consumption (Hsueh, 2012; Liu et al., 2014). The public buildings, public lighting equipment, private buildings, and members of communities are energy consuming normal-state aggregates. The power of community organizations and residents have a significant influence in promoting community energy-saving policies under the concepts of direction, evaluation, and subsidy, which are helpful in forming a common understanding to realize the promotional effects of community energy-saving policies. This can positively affect reducing urban air pollution.

Natural disasters are occurring more frequently than in the past, and they are becoming increasingly severe, causing greater damage than expected. Considerations of the ideal energy-saving low-carbon life style, using green energy sources, must not



merely be a slogan or a concept, but must be fulfilled in daily life, becoming the norm, in order to slow the deterioration of our living environment. CO<sub>2</sub> emissions can be reduced by adopting subsidy policies that encourage the use of natural energy resources in daily life. Burtraw and Parry (2011) suggested that green energy subsidies return the value of CO<sub>2</sub> emission allowances to households. As communities are the energy consuming basic units of urban development, a widespread understanding of energy consumption within a community can use a subsidy policy to promote green energy concepts for local construction and energy-savings.

The development of green communities is conducive to enhancing environmental protection (Pîslaru et al., 2008), lowering anthropogenic CO<sub>2</sub> (Grimmond et al., 2002), and mitigating the greenhouse effect and climate change (Pohjola and Valsta, 2007). Promoting green communities can be distinguished as energy conservation development of the entire community and energy conservation of households. Regarding the energy conservation development of the entire community, approaches that can be adopted include carbon sequestration (Benítez and Obersteiner, 2006; Lubowski et al., 2006; McKenney et al., 2004), increasing the number of plants and trees on the sides of roads and in parks in the community, and reinforcing carbon sequestration of the community to improve air quality and yield environmental benefits (Kula and Gunalay, 2012). Solar-powered devices (Wright et al., 2010; Yang et al., 2011) and LED (Jacob, 2009) can also be introduced, and solar-powered lights on community streets and solar energy devices in portions of parks can be adopted. Regarding applications for energy conservation in households, Hsueh (2012) noted that government subsidies can improve household facilities and strengthen the social responsibility of people and families, which in turn leads to energy conservation effects. Installing solar energy facilities for roofs, green roofs, LED lighting design, and water and power-saving household appliances is an effective approach for improving residences and houses. Because developing green communities requires large sums of money, it is unlikely for communities and households to receive a full subsidy from the government and see timely effects for improvement. Consequently, the current study recommends that, in addition to subsidizing the development of communities, low-interest financing channels should also be provided for green communities. By allowing areas with a high willingness to develop green communities obtain low-interest financing and higher local construction fees, these areas can immediately transfer and replace energy-saving public facilities.

To examine the effectiveness of reducing urban air pollution, this study applied the Delphi method group decision-making technique (Murry and Hammons, 1995; Ziglio and Adler, 1996) to investigate the criteria used in this study. Furthermore, the AHP multicriteria decision-making technique (Saaty, 1980; Saaty and Takizawa, 1986) was used to determine the relative importance of each criterion and the quantified function in fuzzy logic theory (Hsueh, 2012) and establish a model for quantitative assessments. A multi-criteria decision-making model (MCDM) can be employed by management departments to self-evaluate the effectiveness of policies in resolving problems or as a reference for assessing the provision of grants and low-interest financing to communities affected by policies. This model can also be employed by communities to self-review the effectiveness of community education in promoting urban air pollution reduction.

## The framework of the assessment model

The Delphi method is a research technique that was developed with implicit expert assistance and involves a high degree of professionalism and objectivity. The Delphi method was developed by the U.S. RAND Corporation to assist management in predicting future events. However, its application scope is not restricted to predicting future events (Hsueh, 2015).

The AHP method was first proposed by Saaty and has been widely used for solving multi-criteria decision-making problems. AHP is also commonly applied in social, policy, and engineering decision-making issues (Saaty, 1990; Saaty, 1994), and studies that have applied the AHP method include: Enhancing Sustainable Community Development (Hsueh and Yan, 2011), Estimation and selection of building investment (Dziadosz, 2008), Urban Renewal Proposals, Sustainable urban energy-environment management (Bose and Anandalingam, 1996) evaluation approach for livable urban environments (Chiang and Liang, 2013), sustainable water management (Freitas and Magrini, 2013), uncertainty analysis and risk assessment for sudden water pollution accidents (Hou et al., 2014), Strategic energy management (Posch et al., 2015).

Fuzzy logic theory was first proposed by Zadeh. Fuzzy logic can manage vague information in natural human language, such as uncertainty, complexity, and tolerance for imprecision (Zadeh, 1976, 1996). Fuzzy logic theory is extremely suitable for dealing with highly complex and difficult-to-quantify policy evaluations and has been applied in the following studies: especially group decision-making issues (Hadi-Vencheh and Mokhtarian, 2011; Hsueh and Huang, 2014), Sustainable and efficient energy consumption of corn production (Houshyar et al., 2012), energy consumption estimation (Istrate and Grigoraş, 2010), environmental sustainability, pretreated poultry manure wastewater (Yetilmezsoy, 2012), Fenton's strong chemical oxidation process (Sari et al., 2013), English Academic Writing (Baba et al., 2015), investigate the novel uses of nano suspended lubrication (Ooi et al., 2015), a sustainable supply chain of an apparel industry (Jakhar, 2015).

This study developed a model that combines the Delphi method, AHP, and fuzzy logic theory. This model is highly rigorous and reliable because of the expert assistance we employed to examine the content and participate in group decision-making during the modeling process. The framework of the assessment model is shown in *Fig. 3*. The 12 Delphi experts who assisted in this study had over 15 years practical work experience in a related field; 4 experts were from the architect, 4 were scholars, and 4 public service sector. The group decision-making data collected from the Delphi experts provided the required information for a fuzzy logic model. In a DFuzzy - DAHP model environment, appropriate criteria must first be selected from the complex factors, and then each criterion hierarchy must be completed. After the quantitative natural language membership functions are selected, the fuzzy sets and fuzzy scale set, the fuzzy logic inference system (FLIS) of "IF-THEN rules base," and the DFuzzy - DAHP model can function. the Fuzzy Logic Inference System (FLIS) into four major modeling procedures, such as determining evaluation factors; defining the fuzzy set of input evaluation factors and output values; defining Membership Functions; creating IF-THEN rules; defuzzification; and exporting quantized values (Perng et al., 2005). *Figure 3* is the schematic diagram of FLIS.

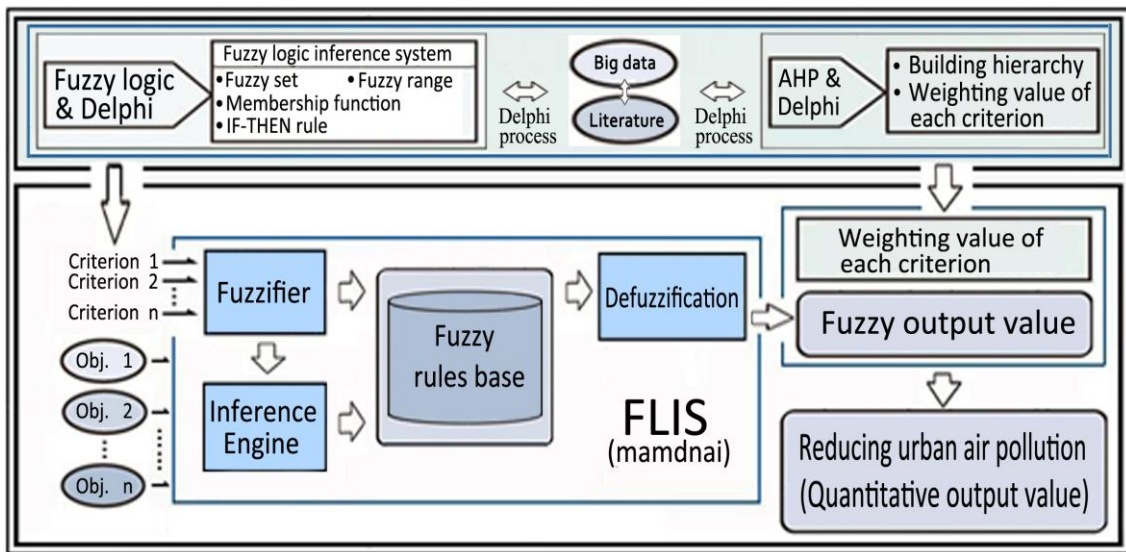


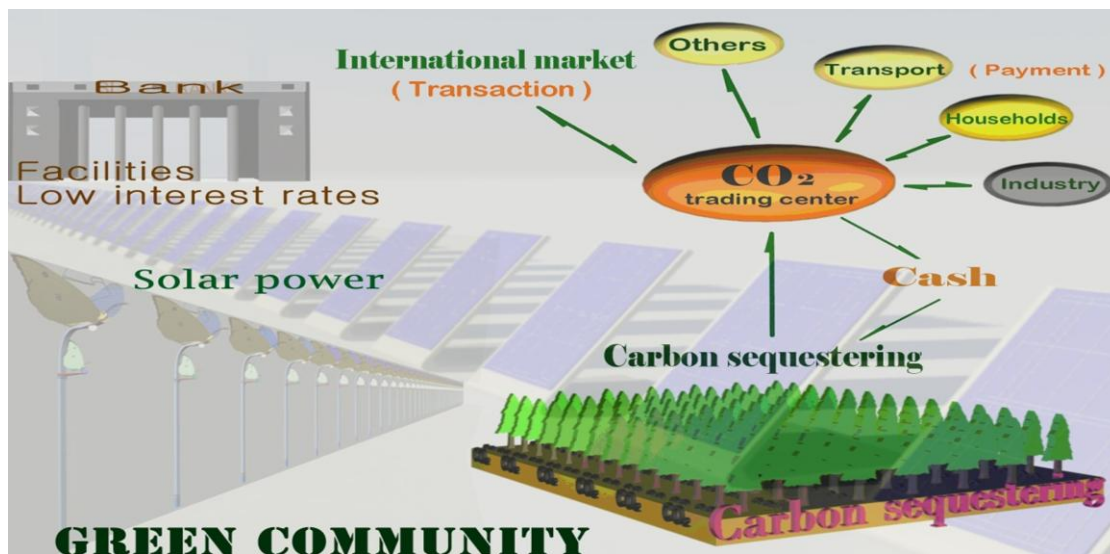
Figure 3. The framework of the assessment model

As shown in Fig. 3, this study first collected relevant literature and big data on improving air pollution in communities. This study also verified the criteria for establishing the AHP and FLIS through the Delphi process. This model is based on the knowledge of several experts and the multiattribute evaluation of big data. Its high objectivity and adaptability render its application easy to maintain, update, and use.

### Criteria affecting air pollution

Developing green communities primarily requires participation from most community residents to achieve energy-saving effects. Mani et al. (2007) noted that a community's attitude and living environment are determinants of sustainability. Furthermore, developing green communities requires investment, which may come from local government subsidies, but also requires low-interest financing from banks; this facilitates the successful development of green communities. After a loan is obtained through community organizations, communities can begin solar-powered street light engineering projects and establishment of solar panels in parks and vacant areas, as well as the planting of trees. Community residents can install solar-powered or solar energy facilities or green roofs. Participation and identification from community residents and their care for tree and forest growth can lead to economic benefits from carbon sequestration and, in turn, minimize environmental pollution. In Europe, carbon is priced at €20/t CO<sub>2</sub> (Lauri et al., 2012). Through carbon trading, communities would be able to generate income from carbon sequestration. Furthermore, investing in solar power energy and generation can be recouped in approximately 15 years. These measures can assist green communities in paying off interest and loans. Figure 4 illustrates the concept for developing a green community that can facilitate air pollution reduction. Vargas-Vargas et al. (2011) indicated that the relationship among economic growth, environmental sustainability, and energy are of great interest to researchers and policy makers. More diverse consideration regarding government subsidies for green

energy would help promote green energy, and long-term low-interest loans for community development of green energy can be refunded or repaid. During the criteria investigation process for this study, Delphi experts agreed that government agencies and community residents who bear social responsibilities should agree to help rapidly complete the development of green communities through low-interest loans.



*Figure 4. Development concept for a green community that enables air pollution reduction*

### ***Selection of initial criteria and evaluating the weighting value***

The preliminary criteria obtained from relevant literature is related to community energy-saving solar electric systems (Black, 2004), using natural energy resources (Lam et al., 2010), resource recovery and reuse, energy-saving materials (Kotey et al., 2009; Lam et al., 2010), planning and designing energy-efficient equipment and energy-saving construction (Nishioka et al., 2000; Sailor, 2008), solar powered energy (Wright et al., 2010; Yang et al., 2011), green roofs (Sari et al., 2013), waste management (Begum et al., 2009), carbon storage in forests (Galik and Jackson, 2009; Pohjola and Valsta, 2007), and urban greening (Nishioka et al., 2000; Taylor, 2008).

According to Dr. Li Nuyun, deputy director of the General Office for Combating Climate Change within the State Forestry Administration of China and secretary general of the China Green Carbon Foundation, “Promotion of forestry carbon sequestration not only absorbs CO<sub>2</sub> but also increases employment opportunities and income for farmers. It also helps elevate farming villages from poverty, maintains and protects biodiversity, and improves the environment, which represents multi-function forestry” (Heilongjiang, 2011). Based on an integration of the aforementioned research content, this study verified the criteria necessary for research by using the Delphi process. As shown in *Table 1*, each criterion in the table was agreed on by the experts.

**Table 1.** Criteria jointly agreed by experts

Criterion	Content
Carbon sequestration	Community planting, family planting, green roofs
Solar power	Solar electric systems, solar materials, solar-powered streetlights
Social responsibility	Resource recovery, community participation, community responsibility, low-interest financing policy

Through the Delphi process, the experts jointly agreed on the criteria. The big data revealed three criteria for effectively reducing air pollution in communities: carbon sequestration, solar power, and social responsibility. These three criteria were used as the basis for establishing the AHP to explore their relative weighting values, and for establishing the main input criteria of the FLIS. To explore the relative weighting value of these three criteria, we requested professionals to assist with the AHP questionnaires and obtain complete and valid questionnaire data. We adopted a strict attitude in completing the AHP process. All of the experts who assisted with the 65 valid questionnaires during the AHP process had 15 years or more work experience in their related fields. The scholars were a vice chancellor, a dean, and a senior professor at universities ranked in the top five universities in Taiwan. The industry experts were a construction, a real estate, an architect, a CEO, and a project manager with a master's degree. The majority of the government officials also had master's degrees and were all also family members. This study was conducted from October 2012 to Aug 2013 to complete the AHP process. *Table 2* shows the relative weight calculations for each criterion in the overall assessment. The AHP calculation process must adhere to a consistency test consisting of two indices, namely, the consistency index (CI) and the consistency ratio (CR). For the CI, 0 denotes that the survey data are consistent, 1 denotes that the data are erroneous, and  $\leq 1$  denotes that the data are within an acceptable margin of error. For the CR,  $\leq 0.1$  denotes that the survey data are consistent. Therefore, AHP calculation results must correspond to both indices to enable subsequent weighting values to be reference values.

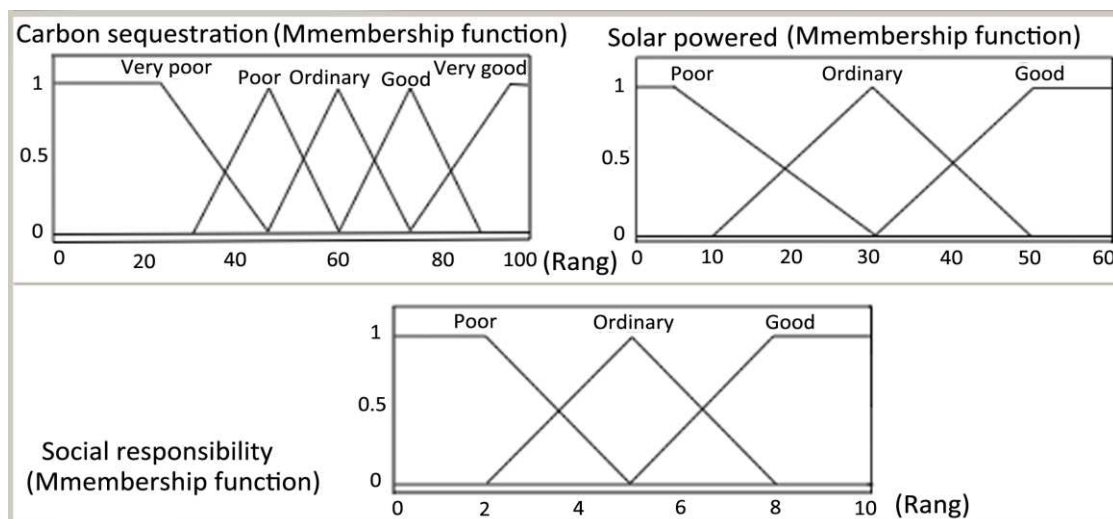
**Table 2.** Weighting value of criteria

Comparison of Carbon sequestration, Solar powered and Social responsibility			
Criteria	Relative weight	Weighting value	Consistency test
Carbon sequestration	1	0.09	C.I. = 0.03
Solar powered	4	0.27	C.R. = 0.05 $\leq$ 0.1
Social responsibility	6	0.64	
Note	1. Relative importance is categorized into 10 levels. The AHP survey results included the relative importance of three criteria. 2. The mean value of the effective survey data was adopted as the comparison value for the relative importance of the three criteria.		

**Defining input and output membership function – fuzzy set of each criterion**

Before establishing the FLIS system, the definitions of the membership function, fuzzy set, fuzzy range of each criterion (including the definition of the membership function and fuzzy range for the fuzzy set of the output value) must be established. When defining the fuzzy quantification of each evaluation criterion or factor, the IF-THEN rule base of the FLIS system is adopted for a proper quantification of assessment problems or topics in different scenarios. As different assessment criteria exert various influences on green community development effectiveness evaluations, the definitions of membership function, fuzzy set, and fuzzy range must be established. Thus, different input scenarios can be input through the IF-THEN rule base to complete linguistic variable calculation and inference (Zadeh, 1975), and the corresponding output evaluation results can be presented. *Figure 5* illustrates the fuzzy set and fuzzy range definitions of three criteria, as well as the fuzzy set and fuzzy logic definitions of corresponding output values. The definition measurement scale in fuzzy logic is an artificial fuzzy scale. For instance, a profit of 90% in carbon sequestration is very good,”60% is ordinary,” and 30% is very poor.” However, whether 75% is good or ordinary is defined according to membership function in the fuzzy logic scale; through the defuzzification of FLIS, the quantified output result can be presented. This is one of the problems that traditional evaluation models can process only with great difficulty.

The evaluation subject is quantized by using different degree values in the fuzzy set when calculating the fuzzy quantized values of three evaluation factors, such as carbon sequestration, solar power, and social responsibility. Because different evaluation factors have different effects on the evaluation of community energy saving, only the range definition of the fuzzy set can present the output evaluation result. A triangular membership function (*Fig. 6*) was employed in the present study. *Figure 4* shows that when the  $x$  value is between  $a$  and  $b$ , the degree of membership of  $x$  in Set A cannot be 0. When  $x$  shifts closer to  $m$ , the degree of membership of  $x$  increases. When the  $x$  value reaches  $m$ ,  $x$  achieves maximum membership in Set A with a value of 1.



**Figure 5.** Membership function, fuzzy set and range definitions of input

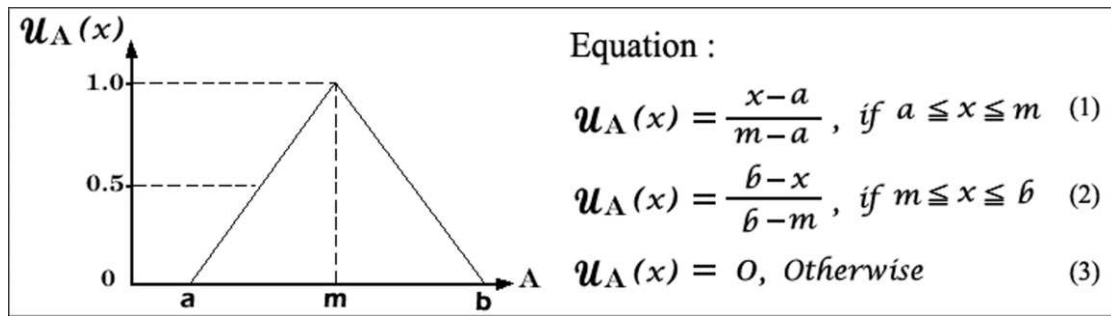


Figure 6. Triangular membership function

### Input scenario and output mapping

After input scenarios are entered into the FLIS system and processed through the IF-THEN rule base inferences, the results are defuzzified and are output as a single quantified value. There are 45 input scenarios in the current model, with three criteria: carbon sequestration, solar power, and social responsibility. Among them, five fuzzy sets are under carbon sequestration and the fuzzy evaluation scenarios include “very good,” “good,” “ordinary,” “poor,” and “very poor.” Moreover, three fuzzy sets are under solar power and social responsibility, resulting in a total of 45 scenarios. Each criterion of the scenarios has a different level of influence on the evaluation of the effectiveness of green community development. The 45 evaluation scenarios are composed of distinct measurement units with multiple attributes that include the ability to process complex evaluation problems. Figure 7 presents the 3D mapping relationships of the input scenarios and outputs for three criteria. This is a computation model that is difficult to achieve artificially or through human development. Moreover, within the overall FLIS, the fuzzy rule base is akin to the human brain. When the FLIS inference rules are established, the FLIS can perform the function of inference and computation. If each evaluation factor is assigned an input value by the decision maker, then the FLIS can automatically calculate the quantified evaluation value of the effectiveness.

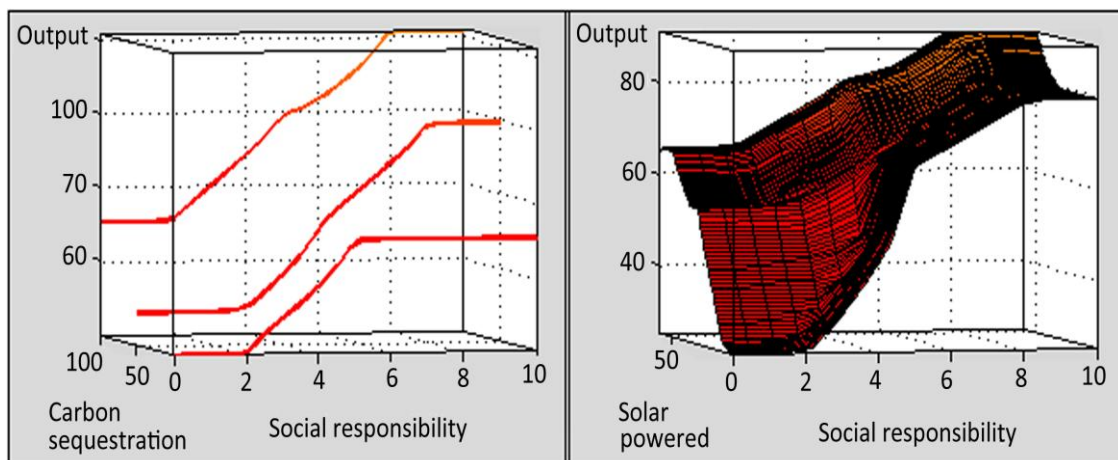


Figure 7. 3D mapping relationships among the input scenarios and output

Table 3 lists the optimal and poorest quantified output values calculated by using the FLIS. The input scenario in Table 3 can be a quantified value or a fuzzy meaning in natural language, such as “good” (high), “ordinary” (medium), and “not good or poor” (low). This is because fuzzy logic bears the function of calculating the linguistic variables and making inferences for linguistic quantification (Zadeh, 1975, 1976). The current model serves as a reference for decision makers prior to project evaluation. By performing accurate and scientific calculation, an additional comparison of the quantified values can become the basis for decisions, thus contributing to the efficiency and effectiveness of the decision-making process and lowering the risks of making poor or incorrect decisions.

**Table 3. Optimal and worst output value**

Criteria	Optimal	Worst
Carbon sequestration	Very good	Very poor
Solar power	Good	Poor
Social responsibility	Good	Poor
Output value (%)	91.0	20.9

### Case study

The fuzzy quantified output value obtained using the FLIS shows the superiority or inferiority of community environmental protection education promotion. If expressed with  $y_i$ , then calculating  $(y_i * w_i)$  demonstrates the latent importance of each criterion, allowing decision makers to easily obtain decision-making information. The community in Case 1 has more space for planting trees and should produce higher carbon sequestration than its counterpart in Case 2. However, the model shows the opposite effect, the community in Case 2 possesses a higher carbon sequestration evaluation. In Table 4, the latent influence of each criterion in Case 2 shows that the community has not only higher carbon sequestration but higher social responsibility. The present case study verifies that participation from community residents is conducive to and has value-added effects for developing a green community. Thus, overall, the community in Case 2 exerted a significant effect on reducing air pollution. In addition, the promotion of community environmental protection education was more favorable in Case 2, and community residents placed a higher amount of emphasis on improving air quality.

The DAHP-Dfuzzy quantitative model was employed to convert 45 input scenarios into a schematic calculation diagram involving the quantified output values (Fig. 8).

**Table 4. Case 1 and Case 2**

Criteria ( $w_i$ )	Case 1			Case 2		
	Scenario	$y_i$	$y_i * w_i$	scenario	$y_i$	$y_i * w_i$
Carbon sequestration (0.09)	Very good	63.3	5.679	Good	82	7.38
Solar power (0.27)	Ordinary		17.091	Good		22.14
Social responsibility (0.64)	Ordinary		40.512	Good		52.48



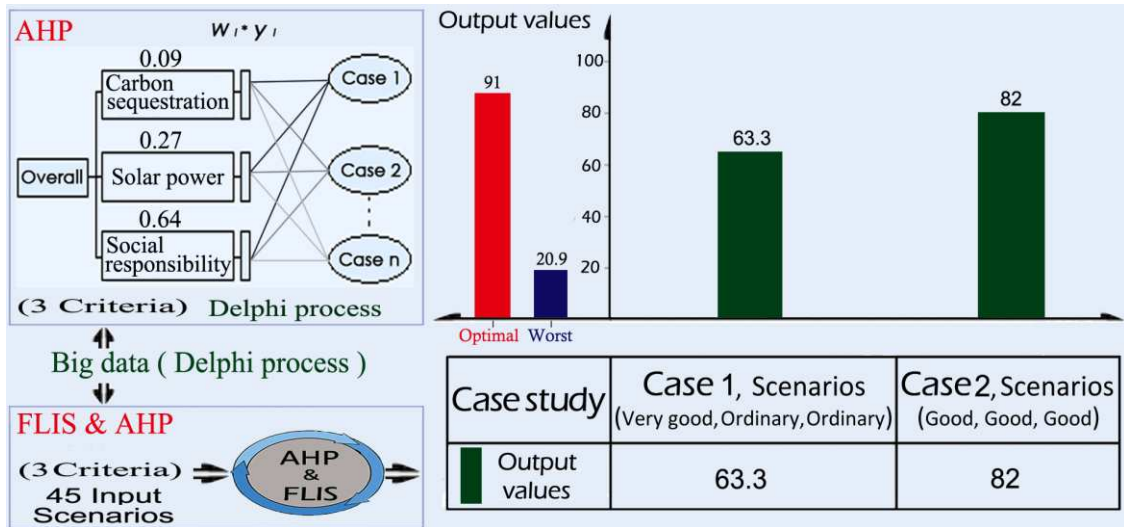


Figure 8. Input and output calculations of the DAHP–Dfuzzy quantitative model

As shown in Fig. 8, this study determined through the Delphi process that the three criteria in the big data influenced the air quality of communities. Their weighting values for carbon sequestration, solar power, and social responsibility are 0.09, 0.27, and 0.64, respectively. The weighting value of carbon sequestration is particularly low, whereas that of social responsibility is particularly high. This shows that the community residents demonstrated a high level of care about the quality of air in their community, but they did not display a high level of willingness for plain afforestation. The results of both cases indicate that the community residents in Case 1 supported plain afforestation, but the overall assessment did not produce a beneficial result because the community lacked the funds and human resources for maintaining and managing the planted trees. This finding may serve as a reference for revising policies regarding plain afforestation and for improving the effectiveness of such policies.

Big data provide critical information from various fields. The effective application of big data creates a virtuous cycle with added-value. It also facilitates uncovering issues and exploring the source of a problem, thereby solving rooted difficult problems. This study verified the criteria for establishing an MCDM model from big data through using the Delphi process. The proposed quantitative evaluation model is not only enables assessing the impact of a single community on air pollution, but it also enables assessing and comparing the positive and negative effects of different communities. The final result could serve as a reference for governmental departments, and could be sent as feedback to the archives of big data for further application.

## Suggestions and conclusion

### Suggestions

When a new policy is promoted, active participation by the public enhances the effectiveness of its implementation. The study found that although the communities accepted plain afforestation, it could not achieve the expected effect because of a lack of

community funds. To ensure that plain afforestation achieves carbon sequestration, thereby improving community air quality, this study proposes two suggestions: (1) offer low interest rates (prime rate) for idle land in communities; (2) establish an emissions trading scheme for carbon sequestration. Accordingly, the public would be required to pay for both the energy they consume and the carbon pollution they generate. Simultaneously, community residents and groups who are keen on promoting plain afforestation can use the payment for funding the long-term maintenance of tree plantations.

### **Conclusion**

Various big data have continued to accumulated, changing the environment in the process of social development. Today, global warming, climate change, and disasters affecting biological diversity are not accidental events. Big data show that the problem of high CO<sub>2</sub> emissions is caused by the long-term excessive use of energy by humans. The analysis of big data and application of derived information would facilitate investigating the fundamental factors of environmental pollution, and would also assist in proposing effective solutions. Community education and promotion aids residents in understanding the importance of public policies and enhances their participation in resolving problems related to such policies. In recent years, industrial development has caused extreme energy consumption and emission of large amounts of greenhouse gases, polluting the environment and causing abnormal climate changes that increasingly threaten human life and property. If the cap-and-trade rules remain unable to restrain human materialistic needs, green efforts exerted will not conspicuously reduce the rate and influence of CO<sub>2</sub> emissions. The evaluation model for reducing urban air pollution established in this study incorporates green community development, social responsibility, and low-interest financing, and can be used to assess community residents' participation and acceptance and to motivate developing the habit of caring for the environment. In addition, fuzzy logic includes artificial intelligence functions, and when combined with the AHP model, it can enable decision-makers to comprehend the relative importance of factors influencing decision-making for complex topics. Moreover, the concerns to be assessed can be converted to numbers or proportions that are easily understood. The developed model is a scientifically derived set of objective quantitative assessment model that can facilitate comprehensively assessing the latent factors of a topic and promoting the development of urban air pollution reduction plans.

**Acknowledgements.** We thank the Dahu Community in Kaohsiung City for funding this study on community afforestation (Zihao-Dahu Community-Mei Zihao-100122) and providing relevant research assistance.

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## EVALUATING THE LEISURE BENEFITS OF ECOTOURISM WITH DATA ENVELOPMENT ANALYSIS

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(Received 11<sup>th</sup> Aug 2016; Accepted 15<sup>th</sup> Nov 2016)

**Abstract.** When people increase the leisure time, leisure and recreation become an important industry in the economic transition under the trend of rapidly growing tourist attendance and enhancing travel expenses. To cope with such a development trend and satisfy the increasing recreational demand of the public, the government and the civil sectors have invested in the development and establishment of leisure and scenic recreation spots and facilities. Participating in ecotourism and developing ecotourism activity become the fashion. In this study, DEA is applied to measure the leisure benefits of ecotourism and properly select the input and output factors to efficiently evaluate the leisure benefits of ecotourism parks. According to the efficiency acquired with DEA and the information of variables, 1 DMU, about 10% of all DMUs, presents relatively strong efficiency on the leisure benefits, with the efficiency=1, revealing the better relative efficiency; 6 DMUs, about 60% of all DMUs, show relatively marginal efficiency between 0.9 and 1, revealing that the relative efficiency of such ecotourism parks can be easily enhanced; and, 3 DMUs, about 30% of all DMUs, reveal obvious inefficiency, with the efficiency lower than 0.9. Suggestions are proposed based on the results, expecting to promote ecotourism and achieve the sustainable development.

**Keywords:** *labor, financial, economy, attraction, performance*

### Background and motivation

The economic development, convenient transportation, and increasing national income in recent years have the people largely grow the demand for natural tourism. The tourist person-time is therefore growing rapidly. When people increase the leisure time, leisure and recreation become a primary industry in the economic transition under the trend of rapidly growing tourist attendance and enhancing travel expenses. To cope with the development trend and satisfy the increasing recreational demand of the public, the government and the civil sectors therefore invest in developing and establishing scenic spots and facilities for leisure and recreation, from the re-planning and recovery of hiking trails to the development and investment of national parks, forest recreation areas, and large amusement parks. Following the governmental promotion of national travel, some tourists do not want to repeat others' practice, but pursue novelty, knowledge, and new experiences, admire the nature, and seek for excitement. Furthermore, the propaga-

tion of news media has lots of people change the aspect to special travel activity like ecotourism so that participating in ecotourism and developing ecotourism activity become the fashion. In terms of providing local citizens with different economic opportunities, taking conservation and economic development into account is a common principle in the world to utilize ecological resources. The purpose of ecotourism is to subsidize the benefits of local communities with the profit of marketing for tourism. Since ecotourism conforms to the idea and principle of sustainable development, it becomes more critical to promote ecotourism and achieve sustainable development. Relevant issues to ecotourism, considering how to reduce the impact of ecotourism on natural environments and maintain the rights of descendants enjoying natural resources and environments, are therefore discussed domestically and internationally.

## Literature review

### *Ecotourism*

Ramdas and Mohamed (2014) mentioned about Hetzer, in Links magazine, advising culture, education, and tourism industries to re-consider the definition of recreation and the impact resulted from tourism, based on sustainable development and management, and proposing “ecotourism”. Zhou et al. (2013) regarded ecotourism as to generate the minimum environmental impact, utilize local culture to generate the maximum economic benefits for the minimum impact on tourist spots, and provide visitors with the maximum recreational satisfaction. In face of current wave of sustainable management, the carrying capacity for the continuous operation of ecosystem and the saturation point of not being able to recover are concerned from the aspect of ecologists. From the aspect of economists, the issue of continuous management from the economic activity of manufacturers and consumers and distinct resource exchange is discussed. Chiu et al. (2014) pointed out the key of ecotourism being the tourism of natural resources in which visitors did not simply pursue brand-new experiences, but searched for the assistance and guidance of interpreters and tourism businesses to enhance the understanding of local culture (covering humanities and nature) and further understand the economic benefits resulted from travel activity so as to conserve local resources. Ahmad (2015) regarded ecotourism as the travel pattern initially based on local nature, history, and intrinsic culture. Ecotourists, who visited undeveloped areas based on the spirits of appreciation, participation, and perception, would not cause expendable damage on wild creatures and natural resources in the travel process but contributed to the living economy of local citizens through employment or other economic tactics. Wong et al. (2012) indicated that local governments regarded ecotourism as a management strategy to acquire funds for building or developing the place and communities through business management. The cognitive component was referred to direct experiences, or information acquired from various channels, to form the knowledge and perception of the subject matter of attitudes. Hanington and Martin (2012) proposed the principles of ecotourism as the development without damaging resources and with attention to environmental sensitivity, offer of the first-hand cooperative and beneficial experiences, and presentation of educational value for local communities, governmental and non-governmental organizations, industries, and visitors (before, after, and during the travel).



### ***Leisure benefits***

Wu (2012) mentioned the abroad meaning of leisure benefits. Some researchers discussed from the viewpoints of physiology, psychology, sociology, and economics, while others studied from the aspects of function, education, demands, and recreation experiences. Ahmed et al. (2015) regarded benefits as profit making related to personal goals. The benefits of leisure activity could assist in the achievement of personal goals, as individuals believed that the physical and mental health could be improved to stabilize the spirits and satisfy physical, mental, and social demands by engaging in leisure activity through the achievement of goals and personal subjective leisure experiences in the process or after the activity (Lu and Stepchenkova, 2012). Ly and Bauer (2014) emphasized that benefits were the improvement of individual demands or physical environments. Literally, leisure benefits were the advantages acquired from engaging in leisure activity that it might be the achievement of goals or the assistance of the engaged leisure activity in the achievement of goals. Domestic scholars and researchers interpreted the definition of leisure benefits with various subjective feelings and effectiveness from individual or group participating in leisure activity or sports, after the demand and desire were satisfied through the participation and the physical as well as the mental conditions and social level were improved. Kang et al. (2012) integrated leisure benefits into a systematic model and indicated that people were stimulated by external factors of environment, activity, time, and mind when participating in leisure activity, to appear physiological, psychological, environmental, economic, and social effects. Such effects, after self-assessment with subjective feelings, would result in leisure benefits. Buckley et al. (2012) proposed that the achievement of leisure benefits and leisure goal included the goal achieved by the participation in leisure and leisure participants' belief in the achievement of goals. De Gusmão Pedrini et al. (2015) indicated that visitors would be willing to visit a destination or other scenic spots in a same country when they were satisfied with the external factors of environment, activity, time, and mind. Visitors would make personal evaluation with local entertainment activity, destination transportation, price level, and service satisfaction. The perceived leisure benefits of visitors would result in the revisit and recommendation intention or behaviors (Damodaran, 2014).

### ***Performance evaluation***

Husted et al. (2014) proposed that performance evaluation covered the measurement of cost efficiency, cost effectiveness, and service effectiveness and the comprehensive performance could be the overall management performance. 1. Cost efficiency discussed the resource utilization for transport service. 2. Cost effectiveness analyzed the relationship between service consumption and resource input. 3. Service effectiveness discussed consumers' use of transport service output. Lemes et al. (2014) defined performance evaluation as systematically assessing individual differences of employees' job performance in the organization or the job performance of each employee for the basis of personnel management. Chaminuka et al. (2012) indicated that effective performance evaluation should 1. stress on short-term, mid-term, and long-term benefits, 2. take qualitative and quantitative evaluation indicators into account, 3. contain controllable activity, 4. use the cost and efficiency principles in economics for the measurement, 5. focus on the efficiency effectiveness, 6. take strategic, tactic, and operational activity into consideration, and 7. emphasize the match of individual and department interests.

Paulson and Schorr (2015) covered the meanings of efficiency and effectiveness in performance. Efficiency was evaluated with the ratio of output and input, and effectiveness was referred to the achievement of corporate goals. From a different aspect, efficiency referred to doing things right while effectiveness indicated to do right things. Enterprise managers would request for efficiency as well as pursue effectiveness.

### ***Construction of performance indicator***

Cheung et al. (2014) stated that administration performance could be presented with the comparison with oneself on “time” and the comparison with others on “space”. The assignment of evaluation indicators therefore should consider the “representativeness” of indicators, the “consistency” and “universality” of basic data on time and space for calculating indicators, and the “simplicity” for data acquisition and calculation. For selecting indicators, it was important to assign real measurable variables, but the variables were not restricted to measurable items. A complete program evaluation should also contain non-quantitative measurement to take both subjective and objective standards into account so as to draw the effectiveness after the policy execution. The evaluation of indicators would directly affect the evaluation result that the construction of evaluation indicators should consider both accuracy and reasonableness. High-quality evaluation indicators present the following characters (Hultman et al., 2015):

- Being able to reflect the importance of certain character.
- Effectiveness to accurately measure.
- Covering statistical reliability and validity.
- Effectiveness to distinguish differences.
- Practicability conforming to time and money.
- Simplicity for easy comprehension.

Moreover, the construction of indicators should consider the specialties of experts and the fair and open opportunities for the participation and opinion expression of rates, expecting to achieve the consensus through thorough communication and generate suitable evaluation indicators (Jung et al., 2015). In sum, Delphi Method is utilized for selecting the performance evaluation indicators of local governments. Delphi Method, also called expert judgment method, is a group decision-making method with both qualitative and quantitative characteristics. Based on interdisciplinary and future orientation, it could acquire a commonly acceptable answer, when certain issues are lack of data or under unknown situations, by several runs of votes and feedback till the lowest opinion difference appears among anonymous experts.

According to the suggestions in the literature, Lo and Jim (2015) explained the so-called “expert” (1) presenting the common interest to attend the Delphi Method survey, (2) showing rich information for sharing, (3) being publically recognized the knowledge and technology in special field, (4) revealing specialties on the survey subject, including practical experiences and theoretical research, and (5) agreeing with the research results containing the special information owned. Maulidya et al. (2014) also pointed out knowledge standards, reliability, and accuracy as the key elements of experts who should know the industry deeper than laymen so that the judgment was closer to facts. The value of Delphi Method was established based on such answers.

## Research indicator and subject

### *Establishment of evaluation indicator*

Proper input and output factors should be selected when applying DEA to measure the leisure benefits of ecotourism, in order to efficiently evaluate various leisure benefits of ecotourism. To combine the input and output factors with expert opinions, reduce the input cost, and avoid fuzziness in the survey process, Fuzzy Delphi Method is utilized for selecting the input and output factors. Total 30 copies of questionnaires are distributed for this study, and 26 valid copies are retrieved, with the retrieval rate 87%. According to Sarrafzadegan et al. (2012), the public opinions of more than 5 participants could be used as the analysis basis. Moreover, the interviewed experts cover industry, government, and academia, with frequent interaction between ecotourism and leisure benefits, that they present certain representativeness.

The evaluation indicators are established based on Delphi Method. The variables are defined as below:

(1) Input variable

- Financial dimension: expenditure of an ecotourism park.
- Labor dimension: invested manpower in an ecotourism park.

(2) Output variable

- Economy dimension: net income of an ecotourism park.
- Attraction dimension: number of tourists in an ecotourism park.

### *Research method and subject*

With Delphi Method and Data Envelopment Analysis, the open statistical data in public sectors are regarded as the input and output performance to select the indicators. The data are proceeded empirical analyses for the reference of ecotourism parks making improvement. Ten major ecotourism scenic areas are selected as the research subjects, as 10 evaluated DMUs, in this study.

## Empirical analysis of local government efficiency

### *Analysis of local government efficiency*

The DEA efficiency evaluation results could help understand the relative efficiency of the leisure benefits of ecotourism parks. The efficiency=1 stands for the DMU achieving the relative efficiency. Contrarily, the efficiency<1 refers to the relative inefficiency of a DMU. The experimental results (*Table 1*) show that Qiandao Lake in Zhejiang is relatively efficient, with the efficiency=1, i.e. Qiandao Lake in Zhejiang achieving the ideal state, while the rest ecotourism parks appear relatively worse efficiency.

### *Slack variable analysis*

Regarding the analysis of returns to scale (*Table 2*) Qiandao Lake in Zhejiang, with fixed returns to scale, shows the optimal leisure benefits, while the rest ecotourism parks present decreasing returns to scale, revealing that the marginal return could be expanded the scale in order to enhance the efficiency.

**Table 1.** Relative efficiency of ecotourism park leisure benefits

Ecotourism park	Overall efficiency	Pure technical efficiency	Scale efficiency
Sand Lake in Ningxia	0.94	0.92	0.95
Jiuzhai Valley in Sichuan	0.96	0.92	0.98
Paektu Mountain in Jilin	0.98	0.96	1.00
Qiandao Lake in Zhejiang	1.00	1.00	1.00
Qinhai Lake in Qinghai	0.99	0.99	0.99
Wuyishan in Fujian	0.95	0.93	0.98
Namtso in Tibet	0.80	0.75	0.85
Pudacuo National Park in Yunnan	0.83	0.78	0.88
Fanjingshan in Guizhou	0.86	0.83	0.89
Shennongjia in Hubei	0.90	0.90	0.91

**Table 2.** Improvement of ecotourism park leisure benefits

Decision-making unit (DMU)	Improved input		Improved output	
	Financial dimension	Labor dimension	Economy dimension	Attraction dimension
Sand Lake in Ningxia	1	1	1	1
Jiuzhai Valley in Sichuan	1	4	2	2
Paektu Mountain in Jilin	2	3	0	3
Qiandao Lake in Zhejiang	0	0	0	0
Qinhai Lake in Qinghai	3	0	1	0
Wuyishan in Fujian	0	2	2	1
Namtso in Tibet	3	3	3	2
Pudacuo National Park in Yunnan	4	4	2	5
Fanjingshan in Guizhou	2	3	1	2
Shennongjia in Hubei	1	2	2	1

Data source: Self-organized in this study.

The results of Slack Variable Analysis, regarding the improvement direction of the leisure benefits of ecotourism parks are shown in *Table 2*. By increasing input units to the items with few inputs, the leisure benefits could achieve the efficiency. Furthermore, the input resource of the leisure benefits of Qiandao Lake in Zhejiang has achieved the optimal use.

## Conclusion

The efficiency acquired with DEA and the information of variables are classified in *Table 1*, where 1 DMU, about 10% of all DMUs, presents relatively strong efficiency on the leisure benefits, with the efficiency=1, revealing the better relative efficiency; 6 DMUs, about 60% of all DMUs, appear marginal inefficiency with the relative efficiency in 0.9-1, showing that the relative efficiency of the leisure benefits of such ecotourism parks could be more easily promoted; 3 DMUs, about 30% of all DMUs, reveal obvious inefficiency with the efficiency lower than 0.9, among which Namtso in Tibet appears the lowest efficiency 0.80. The DEA evaluation results reveal high proportion of leisure benefits not achieving the scale efficiency that the input of leisure benefits of ecotourism parks requires reconsideration and readjustment in order to enhance the competitiveness.

Apparently, Qiandao Lake with the reputation of “the best water in the world”, located in Jiangnan where the landscape is as beautiful as a picture, also has the reputation of “the most beautiful lake in China” and is the first national park of China with Chinese AAAAA-rated tourist attractions. Such unique geographic conditions create the scenery as beautiful as Guilin scenery. With surrounding green mountains, glittering lake, and elegant natural landscape, the different expression on the water surface of Qiandao Lake, with various peninsulas and peaks, is like a maze. Qiandao Lake has received “Qiandao Lake the best scenic spot”, “star service excellent unit”, and “reliable unit in Zhejiang Province for consumers” with the highest visitor satisfaction, the richest tourism programs, the most visitors hosted, and the best economic and social benefits.

## Suggestion

According to the research results and discussions, the following suggestions are proposed in this study:

- Information related to ecotourism should be promoted, especially on the Internet, newspaper, and magazines. Detailed instruction of scenic tourist spots, transportation routes, accommodation information, hotel rankings, seasonal specialties, and mass transit schedule and pick-up locations should be provided. Besides, the most accurate and complete tourism information should be regularly updated for the public to be able to easily and completely planning the tours.
- In addition to interpreters, personnel in visitor service centers should present some knowledge of ecotourism so as to increase visitor intention to participate in ecotourism.
- Distinct ecotourism itineraries could be arranged for different seasons, allowing visitors understanding local culture and life. Moreover, the cooperation with schools for field trips could enhance national literacy of ecology, increase ecological experiences, and know local culture. The premise is that the ecotourism principles must be actually practiced to achieve the educational effectiveness by matching with the ecological culture education policy of the government.

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# AN EMPIRICAL STUDY ON THE EFFECT OF ATTRACTIVENESS OF ECOTOURISM DESTINATION ON EXPERIENTIAL VALUE AND REVISIT INTENTION

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(Received 27<sup>th</sup> Aug 2016; accepted 17<sup>th</sup> Nov 2016)

**Abstract.** When people are satisfied with the material life, they have abundant financial capability and time to stress on the leisure life so that the selection and frequency of recreation have been largely enhanced. A lot of touring spots attract people who live in urban jungles to visit the countryside with the ecological environment and historic and cultural monuments for appreciating landscapes and experiencing the local culture. Aiming at visitors to Maqaw National Park, a total of 400 questionnaire copies were distributed and 326 valid copies were returned with a response rate of 82%. The research results indicated that 1. The attractiveness of a destination presents significantly positive effects on the experiential value; 2. The experiential value shows remarkably positive effects on the revisit intention; and 3. The attractiveness of destination reveals notably positive effects on the revisit intention. According to the results, suggestions are proposed for the reference of recreation planners, government departments, and successive researchers.

**Keywords:** *interpersonal motivators, service superiority, aesthetic feeling, playfulness, consumers' return on investment*

## Introduction

After being satisfied with the material life, people have abundant financial capability and time to focus on their leisure life and participate in recreational activities. As the environment that is suitable for living and activities is limited, the selection and frequency of recreation are largely increased for the public. Public travels mainly involve in the “natural landscape appreciation”, which is followed by the “cultural experiential activity”. To cope with the requirements, a lot of touring spots would attract people who live in urban jungles to visit the countryside with the ecological environment and historic and cultural monuments for appreciating landscapes and experiencing the local culture. To develop tourism businesses, it is necessary to understand visitors' recreational behaviors and the factors in the attraction of recreation. During the consumption process, consumers would refer the perceived value to the purchase decision-making and the purchase of high-value products. A lot of researchers regard customers as emotional, rather than rational, who expect pleasant perception during the consumption process and emotional reactions during the consumption situation. Besides, using products in a leisure and funny process could help customers present high-value perception in order to enhance the purchase intention. Consumers would make purchase or repurchase decisions merely when they consider the advantage and meaning of a product or a service. A repurchase decision would result in the revisit intention, which refers to visitors being willing to visit the tourist destinations or other



touring spots in the same country. As a result, the goal of this study is to understand and discuss the effect of attractiveness of ecotourism destinations on experiential value and revisit intention.

## **Literature review**

### ***Attractiveness of destination***

Attractiveness, as the permanent power established in the same region, contains planned and developed places, such as cinemas, sports centers, theatres, and retail markets, and could provide consumers with places for education, interests, activity, and entertainment (de Ávila., 2011). In addition to the nature and human landscape, the attractiveness of an area could be created through human managements so as to combine and construct skills and strategies which could successfully induce consumers (Lemes et al., 2014). "Attractiveness" indicates that an object is attracted by the specific style of information from the subject to further appear the intention and actions for the satisfaction. Attractiveness shows the characteristics of recreation resources and special charm created by people, or the service and facilities which could satisfy consumer needs to enhance the interests in visit (Hultman et al., 2015). Accordingly, the attractiveness of an area not only is simply the nature and human resources of the area, but also includes the promotion and establishment of the area to build the attractiveness to appeal to population. For instance, by observing artificial landscape resources from consumer behaviors and the attractiveness of an area (Buckley et al., 2012), attractiveness acts as an important catalyst in visitors' participation motivation and the antecedent of participation motivation for the set-off effect (Ke, 2012). In short, attractiveness provides consumers with major motivation for action. Attractiveness is also a primary element in a tourism system allowing consumers to present the motivation so that an area without attractiveness could not permanently develop the tourism industry (Lo and Jim, 2015).

Referring to Chiu et al. (2014), the basic travel incentive is divided into four dimensions in this study.

- (1) Interpersonal motivators, including visiting friends and relatives, making new friends in other places, and getting rid of work and family affairs.
- (2) Physical motivators, containing rest, play, exercise, and therapy.
- (3) Status and prestige motivators, covering exchange, inspection, conference, and personal research.
- (4) Culture motivators, referring to understanding and appreciating the culture, custom, language, art, and religion in other countries.

### ***Experiential value***

Damodaran (2014) advocated that experiences are the economic product of services, starting from customers' consumption experiences, allowing consumers to be integrated into the situation through experience exhibition so as to create unforgettable experiences. In this case, the experiences of people would not be identical, because experiences exist in personal mind and they are internal and acquired through the participation in knowledge, emotion, and shape. Products, as a service, aimed to provide consumption experiences; however, consumers did not really want the product but

rather the satisfactory experience, which was achieved through activity and between external economic activities and the internal world of a person. Ahmad (2015) indicated that recreation and tourism experience could be regarded as the subjective psychological state of a participant, and recreation experience was the comprehensive perception of all experience. Such an experience was acquired by visitors spending time on specific touring spots. Chaminuka et al. (2012) regarded value as a persistent belief and the preference of human actions which had the society or an individual prefer the existing purpose or certain behavior models, but not the opposite or relative purposes or behavior models. Husted et al. (2014) referred to “experiential value” as the cognition and relative preference for product attributes and service performance, which could enhance the value through interactions. However, an interaction, containing the subject-object relationship, might help or hinder consumers from achieving the goal. Bauer (2012) proposed that the experiential value was consumers’ consumption value created after the experience. Experiential value was the cognition and relative preference for products and services; value could be promoted by an enterprise offering a product or a service by interacting with consumers; however, interactions could help or hinder the achievement of consumer goals (Ly and Bauer, 2014).

The classification of the experiential value proposed by Jung et al. (2015) is highly praised that it is adopted as the dimension in this study.

- (1) Consumers’ return on investment: Consumers’ return on investment contains time investment, behavior, and financial investment, as well as psychological resources which could generate potential benefits.
- (2) Service superiority: Service superiority is the internally passive reaction of consumers, coming from a consumer’s praise of a market service (de Gusmão Pedrini et al., 2015).
- (3) Aesthetic feeling: Aesthetic feeling refers to the directly perceived experience of consumers, including the senses of taste, touch, vision, and hearing of products, inner perception, enterprise environment, characteristics of aesthetic feeling, and psychological climate (Satyanarayana et al., 2012).
- (4) Playfulness: The transaction of playfulness is the happiness of an inner reaction to induce inner perception with attractive activities and provide the need to temporarily escape from the reality (Reimer and Walter, 2013).

### ***Revisit intention***

Revisit intention, as the intention to recommend, broadly refers to visitors being willing to revisit the same destination or place, because of satisfactory travel experiences, and recommend the area or place to friends to form the word-of-mouth loyalty and suggestion. Revisit intention reveals the close concept to loyalty, referring to repurchase intention in the attitude and intention dimensions in loyalty theory. Some researchers also paid attention to the correlations between loyalty and revisit intention (Ahmed et al., 2015). Under such an idea, visitors’ revisit shows great meaning on managing and knowing visitors’ needs in tourism industry (Maulidya et al., 2014). Lu and Stepchenkova (2012) referred to a revisit as consumers being willing to visit the same destination or other touring spots in the same country that the convenience of visitors’ previous “number of times”, “transportation in destination”, “travel experience”, and “entertainment”, the “economic” or “political factors” of “local price level” and “local hospitality”, and visitors’ “service satisfaction” and “recreation

product” would affect visitors’ revisit intention to the tourist destination or country. In this case, visitors would present higher revisit intention merely when perceiving better recreation experiences than expectation. Hanington and Martin (2012) discussed the visitor satisfaction with destination from “destination environment and facilities” and indicated that visitors presenting higher satisfaction with destination environment and facilities would enhance the revisit intention. Kang et al. (2012) mentioned that visitor behaviors contained the future behavioral intention, selection of touring spots, and the evaluation after travel. Evaluation after travel covered travel experience, perceived quality in the travel, perceived value in the travel process, and the overall satisfaction. Moreover, the future behavioral intention was referred to as the revisit intention and intention to recommend.

The revisit intention scale, which Cheung et al. (2014) used for measuring package tours, is used for measuring the revisit intention in this study.

### ***Research on attractiveness of destination and experiential value***

Husted et al. (2014) stated the positive and significant effect of visitors’ attractiveness of destination on experiential quality and the indirect effect of perceived value and experiential quality on visitors’ behavioral intention (Ramdas and Mohamed, 2014). It was clear that water activities in Penghu showed high attractiveness to visitors. According to visitors’ travel experiences in Penghu, visitors showed favorable experiences in Penghu and the attractiveness and travel had visitors perceive the value (Reimer and Walter, 2013). Zhou et al. (2013) proposed the recreation experience theory and indicated that visitors involving in travels because of motivation would appear experiential behaviors and acquire expected satisfaction from the experience to further show the behavioral intention. Relevant research proved the remarkably positive correlation between travel motivation and experience (Shen, 2013), notably positive effects of participation motivation on satisfaction with the recreation experience (de Gusmão Pedrini et al., 2015), and positive recreation motivation, experiential perception, and experience satisfaction (Maulidya et al., 2014). The following hypothesis is therefore proposed in this study.

H1: Attractiveness of a destination shows significantly positive effects on the experiential value.

### ***Research on experiential value and revisit intention***

Visitors’ recreation experiences would affect the revisit intention, and the higher experiential value results in the higher revisit intention. Samdin et al. (2013) considered that satisfactory experiential value did not simply present visitors’ internal perception of recreation participation, but could effectively predict the revisit intention. Accordingly, it was primary to enhance visitors’ experiential value in order to promote the revisit intention. Zsóka et al. (2013) discussed the tourist attractiveness, recreation experience, recreation satisfaction, and revisit intention to Tahu Township in Maioli and found out the positive correlations among tourist attractiveness, experiential value, satisfaction, and revisit intention. Regarding the prediction of visitors’ “revisit intention”, recreation satisfaction and the factors of hospitality service, product service, personnel service, and landscape present the biggest influence on the revisit intention. Accordingly, the following hypothesis is proposed in this study.

H2: Experiential value reveals remarkably positive effects on Revisit intention.

### ***Research on attractiveness of destination and revisit intention***

In the research on Kaohsiung International Container Arts Festival, Teksoz et al. (2012) discovered the notable correlation between the overall attractiveness and the revisit intention. Senyolo et al. (2014) combined product perception, interests, familiarity, and purchase in consumers' purchase process to study the effects of destination familiarity (having been to the place) on future intention that consumers' purchase decision-making (i.e., revisit) might be updated (Ahmed et al., 2015). Lu and Stepchenkova (2012) discussed the relationship among the perceived value, loyalty, satisfaction, and revisit intention after golfing experiences. The research result revealed that the perceived value, loyalty, and satisfaction could explain golfers' revisit intention. Cheung et al. (2014) investigated the causal relationship among motivation (divided into push and pull), satisfaction, and tourist attraction loyalty, where loyalty was divided into recommendation to others and revisit intention. Wu (2012) surveyed 282 visitors for the relationship among service quality, behavioral intention, and satisfaction in wildlife refuges. The results showed the significant effect of service quality and visitor satisfaction on the revisit intention. Consequently, the following hypothesis is proposed in this study.

H3: Attractiveness of destination presents notably positive effects on revisit intention.

## **Sample and measurement indicator**

### ***Research sample and subject***

Visitors to Maqaw National Park, as the research samples, are distributed and collected the questionnaire on-site. A total of 400 questionnaire copies were distributed, and 326 valid copies are returned, with a response rate of 82%. Maqaw National Park, also known as Qi-Lan National Park, was built as a national park in Taiwan. It covers Yuanyanghu Nature Reserve and Qi-Lan wildlife habitat, two nature conservation areas announced by Forestry Bureau. The cypress forest in Qi-Lan Mountain is located in the mountains with middle and high altitudes, where the high peaks, deep valleys, and sufficient rain and fog form the closed ecological environment so that rare gymnosperms are associated in the cypress forest, such as Arcto-Tertiary flora of *Taxus chinensis*, *Taiwania cryptomerioides*, *Cunninghamia konishii* Hayata, and *Cephalotaxus wilsoniana* Hayata. The long-term isolation and evolution form the endemic species in Taiwan; therefore, such a rare needle-leaved gymnosperm group evolves for tens of millions of years and even more than hundreds of million years that they could be "living fossil trees". The indicative status in the ecology evolution conforms to Article 8 of World Heritage nomination standards.

### ***Test of reliability and validity***

The so-called validity refers to a measuring tool being able to really measure the questions which researchers intend to measure. Validity is generally divided into the content validity, criterion-related validity, and the construct validity. Since the

questions in this study referred to those proposed by domestic and international researchers, and a pretest is preceded after discussing with the tutor, the research questionnaire presents certain content validity. The dimensions of attractiveness of destination, experiential value, and revisit intention in this study are tested for the overall structural relationship with Linear Structural Relations Model, and the data are based on the correlational matrix of above observation variables. The analysis results with Linear Structural Relations Model revealed that the overall model fit achieves reasonable range that it shows favorable convergent validity and predictive validity.

To further understand the reliability and validity of the questionnaire, reliability and validity analyses were conducted in this study. According to Guilford (1965), the higher Cronbach's  $\alpha$  presents the better reliability. Based on the standard, the Cronbach's  $\alpha$  of the formal questionnaire in this study appears in 0.72~0.88, conforming to the reliability range.

### Analysis of empirical result

The LISREL (linear structural relation) model combines the Factor Analysis and path analysis in traditional statistics and includes simultaneous equations in econometrics so that it could simultaneously calculate multi-factor, multi-causal paths. Regarding the evaluation of model fit, Bagozzi (1998) proposed to evaluate preliminary fit criteria, overall model fit, and fit of internal structure of model.

#### *Evaluation indicator of LISREL model*

According to Kerlinger (1986), item-to-total correlation coefficients could be used for testing the construct validity of questionnaire contents, i.e., judging the questionnaire content with item-to-total correlation coefficients calculated with reliability analysis. The item-to-total correlation coefficients of dimensions in this study are higher than 0.7, revealing certain construct validity of this questionnaire.

The research data is organized in *Table 1*. In terms of the overall model fit,  $\chi^2/DF=1.683$ , smaller than the standard 3, and  $RMR=0.003$  indicated that both  $\chi^2/DF$  and  $RMR$  are proper. Furthermore, the chi-square value is sensitive to the sample size so that it is not suitable for directly judging the fit. However,  $GFI=0.974$  and  $AGFI=0.916$  are higher than the standard 0.9 (the closer  $GFI$  and  $AGFI$  to 1, the better model fit) so that this model shows better goodness-of-fit index.

*Table 1. Analysis of overall fit*

Evaluation	Parameter/evaluation criteria	Result	t
Overall fit	X <sup>2</sup> /Df	1.683	
	GFI	0.974	
	AGFI	0.916	
	RMR	0.003	

Note: \* stands for  $p<0.05$ , \*\* for  $p<0.01$ , \*\*\* for  $p<0.001$ .

### *Analysis of preliminary fit criteria*

The research data is organized in *Table 2*. In regard to the preliminary fit criteria, the explanation of attractiveness of destination (interpersonal motivators, physical motivators, status and prestige motivators, and culture motivators) reached the significance level ( $t > 1.96$ ,  $p < 0.05$ ); the explanation of experiential value (consumers' return on investment, service superiority, aesthetic feeling, and playfulness) reached the significance level ( $t > 1.96$ ,  $p < 0.05$ ); moreover, the explanation of revisit intention reached the significance level ( $t > 1.96$ ,  $p < 0.05$ ). Apparently, the overall model in this study revealed favorable preliminary fit criteria.

**Table 2.** *Analysis of preliminary fit criteria*

Evaluation	Parameter/evaluation criteria	Result	t	
Preliminary fit criteria	Attractiveness of destination	Interpersonal motivators	0.802	9.51**
		Physical motivators	0.795	8.49**
		Status and prestige motivators	0.783	8.23**
		Culture motivators	0.817	10.92**
	Experiential value	Consumers return on investment	0.823	11.48**
		Service superiority	0.759	7.92**
		Aesthetic feeling	0.831	13.23**
		Playfulness	0.813	10.66**
	Revisit intention	Revisit intention	0.826	10.66**

Note: \* stands for  $p < 0.05$ , \*\* for  $p < 0.01$ , \*\*\* for  $p < 0.001$ .

### *Analysis of internal fit*

The research data is organized in *Table 3*. Regarding the internal fit, the attractiveness of destination shows positive and significant correlations with the experiential value (0.876,  $p < 0.01$ ), the experiential value appears positive and remarkable correlations with revisit intention (0.852,  $p < 0.01$ ), and the attractiveness of destination shows positive notable correlations with revisit intention (0.892,  $p < 0.01$ ) so that hypotheses 1, 2, and 3 are supported.

**Table 3.** Analysis of internal fit

Evaluation	Parameter/evaluation criteria		Result	t
Internal fit	Attractiveness of destination→experiential value		0.876	21.69**
	Experiential value→Revisit intention		0.852	19.55**
	Attractiveness of destination→Revisit intention		0.892	26.43**
Research hypothesis	Correlation	Empirical result	P	Result
H1	+	0.876	P<0.01	Supported
H2	+	0.852	P<0.01	Supported
H3	+	0.892	P<0.01	Supported

Note: \* stands for  $p < 0.05$ , \*\* for  $p < 0.01$ , \*\*\* for  $p < 0.001$ .

## Conclusion

The research results indicated the positive and significant effect of the attractiveness of destination on the experiential value and the revisit intention. By analyzing the experiential value of ecotourism, visitors could best associate ecotourism to friendly services and enhance the ecotourism impression by enjoying the package tour. The higher attractiveness would enhance the experiential value. The experiential perception which visitors acquire in ecotourism would affect the revisit intention, and the higher experiential value would result in higher opportunities of visitors' revisit intention. The intention for a visitor to visit an ecotourism park is mainly to get his/her body and mind relaxed and the pressure released. The reason for appreciating natural environment presents the congestion and pressure of the people who live in urban environments and are in search of a temporary escape from their daily life. Visitors would show deeper attractiveness on the monuments, culture, and local specialties in ecotourism parks on the first visit. Those who have visited an ecotourism park for more than twice would pay attention to the participation of festivals and the appreciation of street shows due to their past experiences. It is also suitable for family tours and travels with friends so as to enhance the affection.

## Suggestion

Aiming at the important research results and findings, practical suggestions are further proposed as follows.

1. The initial impression of visitors on ecotourism mainly depends on the introduction and therefore multiple marketing channels become important. However, it is the primary task to master and maintain the access for visitors acquiring information. For this reason, the relationship with marketing channels should be reinforced and a complete ecotourism introduction network should be constructed for a visitor to understand the overall situation of an ecotourism park before his/her arrival.
2. Ecotourism parks are suggested to well utilize the existing environment and resources, develop multiple and playful tours, and get closer to young consumers.

Dynamic participation allows visitors to learn and grow up during the process and offers opportunities for ordinary people to understand ecotourism parks.

3. It is recommended to arrange some artists to perform in the open space so as to enhance the richness of programs, arrange interpreters in some touring spots, and plan a complete touring route. Recreation facilities should be regularly maintained so as to prevent interpretive panels from fading or rusting, which might result in shallow recreation experiences for visitors. The public sections that support the legalization of featured B&B to connect B&B, restaurants, and touring spots could enhance the diversity of the tour and prolong the stay of visitors so as to deliver a deep impression on an ecotourism park.

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## A STUDY ON KEY FACTORS BEHIND THE INTENSIVE DEVELOPMENT OF CHINA'S RURAL HOUSING

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(Received 11<sup>th</sup> Aug 2016; Accepted 15<sup>th</sup> Nov 2016)

**Abstract.** This paper aims to sort out the development history of China's urbanization, analyze the impact of urbanization on the intensive development of rural housing, and summarize the status quo and existing problems in China's rural housing management. On the basis of the foregoing, an intensive development model for rural housing is created, which is oriented towards urbanization, with a view to promoting the development of the new countryside construction. In this research, sample surveys on resident families under the program of intensive development of rural housing in Zhejiang Province are taken as the analysis object. It is concluded from the research that: The most prized dimension is the "governmental factor". The most prized indicator factors include: government-led business operations, urban employment opportunities, scientific planning, residential land use right transfer and residential environment. Based on the analysis of the empirical results, the following conclusions are put forth in this paper. In so doing, we hope to provide clear guidance and direction for the intensive development of China's rural residential houses in the context of urbanization. These efforts will help improve rural housing management, promote the intensive development of rural housing, and contribute to the urbanization process with Chinese characteristics.

**Keywords:** *housing management, urbanization, intensive development, Jiaxing, model*

### Introduction

The formation of metropolises was primarily affected by the human beings' mode of production and economic development, following an evolution from the formation of early tribes through food collection and nomadism to villages mainly engaged in agricultural activities, and finally to the industrial revolution. Population from towns and villages has been flocking to cities, so that metropolises were formed. As a part in the historical category, urbanization is a concept in the process of development. It can be elaborated from different perspectives, including demography, geography, sociology, and economics. Since ancient times, people have been tending to live together for safety, water and food. These places are usually located along important lines of communications, such as ports, railways and other production centers. The invention and popularization of vehicles have enabled people to select relatively distant residential environments so that their living and residential methods underwent changes in the course of movement. In summary, the so-called "urbanization" means the process of the rural population's permanent migration to cities, and the second and tertiary industry's constant clustering in cities, which results in continuous increase in the number of cities and expansion of the urban sizes, as well as the growing dissemination of urban production modes, living methods and core values. As a historical environment, urbanization has become an irresistible trend in the human being's socioeconomic development and civilization progress. With cities being the destinations for

urbanization, the quantity and size of cities will determine the urbanization level. The promotion of intensive development of residential houses in China's rural areas will be conducive to the vigorous development of the urbanization process in the new century.

## Review of Literature

### *New Urbanism*

According to Ho and Gao (2013), New Urbanism is a kind of activity under the modern urban planning, intended to revitalize the redevelopment of the principles and applications of traditional urban elements arising from the late 19<sup>th</sup> century and early 20<sup>th</sup> century in areas to be built. It calls for the changes to an urban form dominated by the traditional residence-business separation, in order to avoid monotonous and isolated urban living space resulting from metropolitan residential area. The New Urbanism has become a most common used method for the suburban development in the United States. In order to realize the dream of calm, peaceful and undisturbed suburban life, the following points must be covered in the physical space planning: (I) Simple residential areas, with the intensity and purpose of use being controlled on the basis of the explicit use zoning; (II) Small-sized recreational vehicles are used as the main means of transport, road and fast road networks are build based on the road hierarchy; (III) People's own residential houses must keep distance from their working place; (IV) Social classes are shown in distinguished areas on the map, indicating city centers are no longer a single core, but has been converted into a convenient transportation hub, a business district and places of residence for the middle and lower classes, while high-earning classes live the suburbs and can use their own car for commuting (Means, 2011); and (V) For urban public facilities, a higher percentage of funds must be spent on roads and parking spaces than previous urban planning. Therefore, roads are primarily used for vehicles (Najafi, 2010). According to Nguyen (2012), in terms of the spirit of New Urbanism, the configuration of buildings and open spaces are used to emphasize spatial scale and density, spatial hierarchy and connectivity, and uphold the planning concept whereby New Urbanism is designed for the whole community based on the similar principles. It is expected to provide a mixed and varied use to meet the needs of local residents. Within the neighborhood center, schools, markets, public facilities, etc. must be made available, while people from the community can reach neighborhood center on foot within five minutes. Its planned cities are classified on the basis of the concept of the neighborhood units. The New Urbanism neighborhood units are governed by the following principles (Opoku and Abdul-Muhmin, 2010):

- It must have a clear center and marginality. Neighborhood unit centers are usually located at important crossroads, and are where public facilities (post offices, cultural centers, etc ...) are located. With squares and green fields used as public spaces, work and shopping center sites can be connected with the centers, and commercial and community activities with neighborhood features can be integrated to enhance the centers' functions. (Habib et al., 2011).
- With 1/4 mile taken as the best neighborhood size and five minutes walking distance as the standard, residents are expected to complete the required activities of daily living within this distance. Stations can be connected with the surrounding areas to increase willingness for commuting.

- Mixed and varied uses will be required. Commercial, residential, work, entertainment and other different functions must be used in combination, and people are encouraged to walk to expand the scope of activities of different ages, and to provide different housing forms, and people with different incomes can be integrated in a single neighborhood (Lai, 2011).
- Buildings and transportation must be covered in a good network. In the street blocks, pedestrians' walking distances will be shortened, and various types of neighborhood streets will be provided for the use of people and vehicles, in order to avoid the entry of transit vehicles into the local streets. Cal-de-sec and ring roads will be utilized to reduce the connection between people and vehicles (Means, 2011).
- Public spaces and buildings must be given top priority. The public nature of public facilities will be utilized to strengthen the relationship between the housing districts, and with the support of and with gradational streets, street blocks and squares, the roles of neighborhood centers will be enhanced so that they become the neighborhood landmark (Zhang et al., 2011).

### ***Review of China's urbanization process***

According to National Bureau of Statistics (2015), China's cities and towns are classified into two types, i.e., large cities and small towns. The word "cities" refers to those cities duly established with the approval of competent governments of the People's Republic of China. Based on the size of non-agricultural population in urban areas, cities are divided into: megacities (with a population of 2 million and above), supercities (with a population of 1-2 million), large cities (with a population of 500,000-1 million), medium-sized cities (with a population of 200,000-500,000) and small cities (with a population of less than 200,000). Originally referring to the places where governments of duly established towns are located, the scope of small towns has since expanded and is determined primarily on the basis of populations and functions. The two major destinations of China's urbanization include large/small cities and towns widely distributed in the rural areas. The urbanization process arising from the intensive construction of rural housing as mentioned herein covers both large/small cities and small towns, with more emphasis placed on small towns in rural areas. The first stage: the stage of steady development (1949-1957). According to Zhang et al. (2011), during the period when New China was just founded, when no clear urbanization policy was formulated, and there was no policy restriction on rural population's entry into cities for settlement and employment, rural population can freely move into cities, which promoted the rapid development of urbanization for this period. The second stage: the stage of fluctuated development (1958-1978). During this period, the urbanization development was affected by the national macro-policy failures and experienced sharp fluctuations. As the iron and steel production campaign ignited a wave of China's industrialization, and rapid development of the industrial sector required numerous labor forces, a large number of rural people moved to work in the industrial sector, which promoted the hyper-growth of urbanization and urban population surge. Starting from 1959, the national economy experienced a severe recession, unable to support the rapid growth of urban population, resulting in a significant decline in urban population, and ushering in a fluctuation period dominated by stagnation and decline. According to Zhang et al. (2011), with the revitalization and consolidation of the national economy in

1964, the population control was modestly relaxed, and by 1965, the urbanization rose to a level comparable with that in 1957. Due to impact of the Cultural Revolution, the national economy stood at the verge of collapse. In the winter of 1966, nearly ten million urban residents in rural areas were repatriated to the rural areas, and in 1968, more than 20 million urban young students were sent to the mountainous areas and the countryside, causing the urban population growth to decline and hover at around 17%. As a result, the urbanization level during this period maintained a stagnant and declining trend. The third stage: stage of rapid development (after 1978) (National Bureau of Statistics, 2015). According to Zhang et al. (2011), after the end of the "Cultural Revolution", the political order was brought out of chaos to normal and policies were adjusted, so that a large number of educated young people sent to the mountainous areas and the countryside as well as cadres transferred to a lower level or to do manual labor in the countryside or in a factory returned to their cities, and the university entrance exam was restored. All these changes resulted in rapid growth in the urban population, relatively rapid restoration of the urbanization level, and rise in the urban population. This symbolizes a rebound from the decline of the urbanization level. According to Babbie (2013), with the rapid development of township enterprises and the rapid increase in small towns since the mid-eighties, the focus of reforms has been gradually shifting to cities. China's industrialization entered a stage of rapid development, resulting in a rapid growth in urban population. Since the beginning of the twenty-first century, China has been making all-out efforts to speed up the pace of urbanization, resulting in a rapid rise in the urbanization rate. During this period, China's socialist market economic system underwent gradual improvement since its establishment, and the pace of urbanization and industrialization was further accelerated. Through the pilot implementation and gradual popularization of the urban and rural area integration reforms starting from 2008, the urbanization level witnessed rapid improvement.

As seen from the perspective of China's urbanization development history, China has emerged from a backward agricultural country with a low urbanization level, and embarked on an evolution from a typical agricultural country to an industrialized and modernized country, after 60 years of development with the support of the country's transformation from a planned economic system to a socialist market economic system featured with reforms and opening-up. Its urbanization level has remarkably improved, and a development road to urbanization with Chinese characteristics has taken shape. All the foregoing developments will provide historical and realistic foundations for the promotion of urbanization construction and development by mobilizing farmers to collectively live in cities through the intensive construction of rural housing.

### ***Analysis on the status quo and existing problems relating to China's rural housing Management***

According to Peng (2009), due to the expanding population in China, the social system transformation and the development of the modernization drive, the contradiction between people and places has become more apparent. It has become an even more arduous task to comply with the red line for arable land. The legislation relating to residential land management is growingly lagging behind. With the vigorous promotion of the construction of the new socialist countryside, the organization of rural

housing is playing a growingly important role in the construction of the new countryside. However, the status quo of rural housing management allows for no optimism. The problems existing in rural housing management lie in the following three aspects:

- Rural houses are constructed in a distracted structure, adversely affecting the urbanization of the rural areas

Given that no sufficient guidance relating to village and town construction is available for the construction of farmers' houses, farmers' houses are constructed in a casual manner, resulting in scattered layout and differentiated structures. A large number of "hollow villages" have emerged, causing severe waste to rural land, poor rural images and lack of infrastructure. The scattered distribution of residential land in the rural areas and the problem of separate arrangements for farmers' housing construction will adversely affect farmers' concentration in cities/towns and central villages, and the popularization of intensive land use and urbanization in rural areas (Najafi, 2010).

- Rural housing is managed in an irregular manner under imperfect market mechanism

According to Peng (2009), no independent laws and regulations are available to govern China's rural housing management. Relevant rules can be found in miscellaneous laws concerning land management. In addition, the local conditions differ greatly across China, and law enforcement is not carried out in a consistent manner, resulting in lack of a unified standard management. Certain serious problems exist, such as farmers' excessive occupation of residential land and invisible transfer of residential land. A market-oriented money-raising mechanism is lacking, resulting in shortage of funds for rural residential land consolidation. The consolidation of rural residential land and concentration of residential areas require a huge amount of funds, which is not affordable by reliance on governmental fiscal subsidies and farmers' own financing. According to Ho and Gao (2013), Infrastructure construction such as old house demolishing, land consolidation, roads, water and power supply and telecommunications require a considerable amount of preliminary funding. Insufficient fiscal subsidies, heavy fund pressure in infrastructure construction, unavailability of supporting funds, lack of incentive measures for farmers' relocation to new village areas and construction of houses, and especially the low level of financial subsidies and allowances for residential land consolidation, have affected farmers' enthusiasm for demolishing the old houses and building new houses, resulting in slow progress in farmers' intensive construction of houses and slow-down in the progress of new village construction (Nieboer, 2012).

- No effective guidance for the intensive construction of rural housing, affecting the development of the modernization drive in the rural areas

According to Peng (2009), no sufficient attention has been given to the consolidation of rural housing. Currently, leading cadres in the rural areas, especially cadres at the county and township levels attach greater importance to economic indicators and place one-sided emphasis on economic growth and increase in farmers' incomes, while no sufficient attention is given to rural social management. In the area of land management, special attention is given to protection of arable land and agricultural land transfer, while the development and consolidation of residential land have not been put on the agenda. No efforts have been made to effectively strengthen the development and consolidation of rural housing, taking into account the requirements for tidy village image in the new village construction, the purpose of ensuring the red line for arable

land, and the necessity for improving farmers' residential and living quality. According to Lai (2011), the role of guiding and constraining the intensive construction of residential housing based on the village and town construction planning has not been sufficiently played. Village/town construction planning should play a leading role in the construction of rural houses and will have a direct controlling impact on the construction of farmers' houses.

For a long period of time, no importance is attached to the planning's guiding roles in China's rural construction. The lagging planning of rural construction, and lack of necessary land use planning, village/town construction planning and planning of arable land consolidation have adversely affected the new village construction. According to Peng (2009), Over the recent years, as the state values and emphasizes the rural planning and construction, rural planning and construction start to make progress, but a number of problems still exist in the scientific, applicable and operable nature of village/town construction planning. Governments at various levels shall assume the major responsibilities for formulating overall land use plans, village/town construction plans, arable land consolidation plans and other plans, and supervising the implementation thereof. The supervision and service functions of governments at various levels shall be continuously strengthened. According to Means (2011), Scientific and feasible village/town construction planning can effectively guide the intensive construction and consolidation of rural housing, which will have a positive impact on the local economic development, and facilitate the construction of public service facilities and the improvement of farmers' living quality. In consideration of this, the intensive construction of rural housing will become an important supporting for promoting the development of the new village modernization drive.

## **Research Design and Methods**

### ***Delphi method***

This method aims to build AHP dimension criteria based on the Delphi Method. The Delphi Method is also called the Method of Specialist Investigation, a decision-making method whereby the problems to be solved are sent to individual experts separately via a proper communication method for comments, opinions are collected from all experts and summarized, comprehensive opinions will be worked and, together with predicted problems, submitted to the experts for further opinions, and all experts will revise their original opinions based on the comprehensive opinions, and the further opinions will be summarized, and unanimous prediction results will be reached gradually upon the repetition of the foregoing processes.

The Delphi Method adopts a method of making anonymous comments based on systematic programs, which means experts shall not discuss with each other and shall have no mutual contacts, and may only have relationship with the surveyors. Through several rounds of survey of experts' opinions on the presented problems, and upon repeated enquiry, summary and revision, a basically unanimous expert opinion will eventually be summarized as the prediction result. This method is widely representative and relatively reliable.



### ***Establishment of evaluation indicators***

This questionnaire will be sent to experts in various areas via email. The first action will be to collect and summarize feedbacks from the experts, and sort out the items to be considered with respect to the intensive development of China's rural housing in the context of urbanization. Subsequently those considerations in similar nature will be put in the same category, and sent to the experts for their comments. Repeated communications with the experts will be conducted until the final opinions are received. Finally, they will be classified by large items, and an expert meeting will be called and experts to gather together to work out the key factors determining the intensive development of China's rural housing in the context of urbanization, i.e., government factor, economic factor and environmental factor. Then an AHP questionnaire will be created by using these key factors as AHP dimensions and various corresponding classifications as the criteria. The key factors revised in the Delphi Method in this research are shown as follows

- Governmental factor: scientific planning, transfer of residential land use right, business activities led by the government;
- Economic factor: urban real estate prices, capitalization, urban employment opportunities, original values of residential land
- Environmental factor: the intensive level of public services systems, residential environment, and reforms of the household registration system

### ***Research object***

In this research, sample surveys on resident families under the program of intensive development of rural housing in Zhejiang Province are taken as the analysis object. In the research, 500 copies of questionnaires were distributed, and 366 valid questionnaires were collected, with a response rate of 73%. At present, in order to reasonably address the contradiction between construction and livelihood, the Jiaying City puts the construction of rural apartments on the top agenda of its village/town construction. Over the recent two years, a total of 6,500 suites of rural apartments have been built, attracting more than 19,500 farmers and saving more than 2,000 mu arable land. This year, the construction of additional 1,100 suites of apartments will be completed. In consideration of this, the residential families of the rural apartments in Jiaying are used as the research samples.

### **Data Analysis and Results**

Upon evaluating all the hierarchical weightings, allocations will be made on the basis of the relative importance of the hierarchical evaluation indicators, indicating the importance of the relevant hierarchy's indicators in the whole evaluation system, and giving rise to an overall weighting for the evaluation of the intensive development of China's rural housing in the context of urbanization, as summarized in *Table 1*.

The following conclusion can be drawn on the basis of the foregoing *Table 1* resulting from analysis and summarization of the questionnaires:

Among the second-level evaluation dimensions, the most valued dimension is the "governmental factor", which has a weighting of 0.412, accounting for 41.2% of the total weighting. Other valued dimensions are respectively "economic factor" (with a

weighting of 0.357) and "environmental factor" (with a weighting of 0.231). It can be learned from the survey result that the most valued dimension for the intensive development of China's rural housing in the context of urbanization is the governmental factor.

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### Conclusion and Suggestions

Based on the analysis of the empirical results, the following conclusions are put forth in this paper. In so doing, we hope to provide clear guidance and direction for the intensive development of China's rural residential houses in the context of urbanization.

*Table 1. Summary of the Overall Weightings for the Intensive Development of China's Rural Housing in the Context of Urbanization*

Dimension	Level 2 Weighting	Level 2 Sequencing	Indicator	Overall Weighting	Overall Sequencing
Governmental factor	0.412	1	Scientific planning	0.123	3
			Residential land use right transfer	0.112	4
			Government-led business activities	0.164	1
Economic factor	0.357	2	Urban housing prices	0.074	7
			Capitalization	0.070	8
			Urban employment opportunities	0.146	2
			Value of original residential land	0.066	9
Environmental factor	0.231	3	Intensive degree of public service systems	0.085	6
			Residential environment	0.097	5
			Reforms of the household registration system	0.063	10

On the basis of analyzing the factors constituting the intensive development model for rural housing, as well as the different roles of the actual and constituent factors in the intensive housing development in different regions of China, the author classifies the intensive development model for rural housing into two types: the model of using rural residential land in exchange for urban housing and the model of waiving rural residential land + economic compensation. Each model includes basic factor, key factor and auxiliary factor. A detailed analysis of two of the factors are provided below.

### ***The model of using rural residential land for urban housing***

The model of using rural residential land in exchange for urban housing is a model whereby farmers use their originally owned residential land in exchange for urban housing pursuant to agreed-upon terms and conditions. Specifically, it can be divided into two forms, i.e., using rural residential land in exchange for urban housing and using rural residential land in exchange for urban housing + industrial premises. Farmers using rural residential land in exchange for urban housing may operate or transfer the contracted land, and normally will not waive the use right to the contracted land. Farmers under the model of using rural residential land in exchange for urban housing + industrial premises may find jobs or start their own businesses in cities/towns, and normally will not operate the contracted land by themselves, but may transfer the right to the operation of the contracted land for profits. This model is suitable for a large number of people and covers a large scope of areas. Farmers may also select using rural residential land in exchange for urban housing or for industrial premises from these two methods. Normally, in economically developed rural areas, farmers tend to select to using rural residential land in exchange for urban housing and using residential land in exchange for urban housing + industrial premises. In rural areas with their economy not sufficiently developed, especially in regions where the second and tertiary industries are not sufficiently developed, farmers tend to choose the method of using their residential land in exchange for houses in central villages, operate or transfer the operating right to contracted land for profits.

### ***The model of waiving residential land + economic compensation***

The model of waiving residential land + economic compensation is a model whereby farmers with their households registered under their respective collective economic organizations waive their originally owned residential land, and waive the entitlement to receive a piece of residential land without charge from their respective collective economic organizations, which is equivalent to waiving their entitlements to receiving residential land in China's rural areas (because under Chinese laws and regulations, farmers can only receive a piece of residential land without charge from the rural collective economic organization under which their households are registered), and will be paid an economic compensation as replacement. The amount of the economic compensation will be determined by the village collective economic organization and the agricultural development company based on the evaluation of originally owned residential land. The most important feature of this model is the waiver of the originally owned residential land and the entitlements to receive residential land without charge. The free allocation of residential land is a welfare guarantee for Chinese farmers. Those who have lost their farmer identity and transformed into urban citizens will

automatically lose such welfare. Therefore, farmers who waive their originally owned residential land will, despite their identity as farmers, no longer engage in production or labor within their collective economic organizations, but will move to be employed by the non-agricultural sectors, and have stable work positions and economic incomes. This model is suitable for urban citizens that are engaging in non-agricultural industrial work, have stable incomes and stable employment, have purchased or plan to purchase urban housing for residence, and have the identity of farmers. In China's eastern regions where the agricultural economy is relatively developed and the rural-urban integration started early, as well as other regions with relatively developed rural economy, this model is more likely to be used. This model can, to the maximum extent possible, reduce the land occupation by rural housing and make it more possible to expand the area of arable land and the quote for the land used for urban construction. In the practice of intensive development of rural housing, the foregoing two models are used concurrently. In the intensive housing development in a certain region, an agricultural development company should also use these two models concurrently. Only in so doing, can farmers select the model of intensive housing development suiting their own needs freely to a certain extent so that farmers' interests can be effectively guaranteed. In summary, for intensive development of rural housing, multiple models should be created whereby to use rural residential land in exchange for urban housing and waive rural residential land + economic compensation, on the basis of scientific planning, law enforcement, farmers' roles and progressive implementation. In the practice of intensive development of rural housing oriented towards urbanization, marketization and modernization, efforts should be made to improve rural housing management, promote the intensive development drive for rural housing, and make contributions to the urbanization process with Chinese characteristics.

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## THE CURRENT CONDITIONS OF CSR IMPLEMENTATION IN CONSTRUCTION INDUSTRY: A LESSON FROM TAIWAN

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** Nowadays, a growing number of companies are starting their corporate social responsibility (CSR) implementation and consider CSR as a kind of business strategy. To understand the current CSR implementation levels in construction industry and identify relatively easy-to-achieve CSR targets for companies interested in CSR, this study is conducted by analyzing the CSR reports of some large-sized companies in Taiwan's construction industry and by conducting a questionnaire survey on large-sized and reputable companies in construction industry to find out the CSR implementation levels of these construction companies and the differences between contractors and real-estate developers in their implementation measures. It found that even if a company in construction industry is interested in CSR implementation or CSR report issuance, it is driven by purposes such as business transformation or investment attraction. Moreover, different types of companies in construction industry have different focus in their CSR implementation dimensions. The contractors focus more on their environmental influence, carbon emissions and impact on biodiversity at their construction sites while the real-estate developers focus more on the pre-construction environmental evaluations of the construction sites and green building designs.

**Keywords:** *corporate social responsibility; contractors; real-estate developers; CSR report; GRI*

### Introduction

In earlier days with less developed information circulation, the construction industry paid little attention to CSR, considering it as merely giving back to society without obtaining any gain in return. Because of the current economic slowdown, large-sized companies in Taiwan's construction industry are not as profitable as before. To ensure more stable profitability and growth, they have gradually started with different new business strategies: growing in size, internationalization. Some of them also have started to regard CSR as a kind of business strategy. CSR is often considered as one of the sources of competitive advantage. In a highly competitive, chaotic and ever-changing environment, socially responsible business behaviors are an effective and necessary strategy to ensure survival and sustainability (Frederick, 1998; Loosemore and Phua, 2011).

Eun et al. (2011) indicate that CSR is an increasingly important topic for academia and also a priority for companies. For development practitioners, CSR has become a major point of interest (Jenkins, 2005). According to Porter and Kramer's (2006), CSR is definitely worthy of consideration. Lichtenstein et al. (2004) contend that CSR can be a feasible promotional strategy to bring broader benefits for the company beyond immediate purchase behaviors. CSR can bring corporate profits and responsible social development (Berkhout, 2005). CSR reflects a growing public demand for greater transparency and accountability of companies. It can be used as a strategy to tackle

externalities and serve as insurance against reputation risks that may damage profitability and corporate values (Ogrizek, 2002). As indicated by Piercy and Lane (2009), the influence of CSR initiatives on customers and other stakeholders is key to better performance. According to the suggestions by Yadong (2007), CSR should include: (1) external dimensions regarding relationships with suppliers and commitments to local community protection and engagement; (2) internal dimensions regarding relationships with employees and unions; and (3) transparency and accountability, including commitments to issuing CSR reports.

The construction process, from planning and design to use and demolition, has a significant influence on society (Fewings, 2009; Murray and Dainty, 2009). In general, the ethical reputation of the construction industry (Huang, 2014) has been quite poor, widely deemed by the public as a sector rife with problems such as corruption, health and safety hazards, and environmental pollution (Moodley et al., 2008). According to Petrovic-Lazarevic (2008), in the Australian construction industry, large companies have implemented CSR in order to be seen as good corporate citizens. Liu et al. (2011) point out that the Department of Trade and Industry in the UK is promoting CSR as a business contribution to sustainable development. Didier and Huet (2008) indicate CSR-related issues are discussed in higher education engineering courses in France but have not been implemented within the engineering-related industries in France. Common Wealth Magazine, a prestigious business magazine in Taiwan, started in 2000 its annual evaluations and rankings of companies' CSR realization in Taiwan. Amidst its "Top 50 Corporate Citizens" from 2012 to 2015, only one company is from the construction industry. Considering the social, economic and environmental impact of construction activities, the construction industry has more reasons to focus on CSR than most others (Murray and Dainty, 2009; Huang and Lien, 2012). Known as the "locomotive of industries," the construction industry is still lagging much behind the service, manufacturing and other industries, in terms of the awareness and implementation of CSR.

From the CSR reports of reputable construction companies, knowledge about the current levels of CSR implementation in the construction industry can be obtained. Among the CSR report writing standards, the global reporting initiative (GRI) is the most widely used. It provides comprehensive guidelines of corporate information disclosure and adopts the mechanism of external auditing, giving trustworthy credibility and transparency to CSR reports based on this standard. Because of its characteristics, the construction industry has more direct impact on the environment than the other industries. Environmental protection is an essential part of CSR. As issues of environmental protection are receiving increasing attention around the world, how to improve CSR implementation has become a priority for large-sized companies in Taiwan's construction industry in their strategic development. Better CSR implementation means not only healthy interactions between the government and the company but also stronger confidence in the company from investors and consumers.

In this study, the CSR reports of selected large-sized companies in Taiwan's construction industry are collected and analyzed to learn about the current conditions of CSR implementation in the industry. A questionnaire survey is also conducted to further explore the trends and problems of CSR implementation among companies in Taiwan's construction industry. To help promote CSR in construction industry, this study is intended to achieve the following purposes:

1. To explore and analyze the current CSR implementation conditions of major construction companies, consisting of both contractors and real-estate developers in this study, in Taiwan through their CSR reports and a questionnaire survey; and
2. To find relatively easy-to-achieve CSR targets for companies in construction industry interesting in starting their CSR initiatives.

## Literature Review and Research Design

### *CSR Standards*

The concept of CSR refers to the responsibilities of a company for its ethical integrity, shareholder interests, labor rights, supplier management, consumer rights, environment, community participation, performance information disclosure, and stakeholders. Nowadays, companies are evaluated mainly based on their business performance not CSR performance. Companies with good CSR records are not necessarily companies with good business performance or profitability. Some regards CSR as companies' returning a portion of what they have gained from society back to society. In other words, in addition to the rights society has endowed upon them, companies have their obligations to society and they have to fulfill their obligations in ways acceptable to society. The International Standardization Organization (ISO) has also established a work group responsible for developing a set of CSR guidelines (ISO26000) and it is believed that ISO26000 will be applied not just to companies.

Among the CSR definitions proposed by many international organizations, experts and entrepreneurs, the following three major elements can be found:

1. Volunteerism as proposed by Steiner (1971): "More power comes with more responsibility" and so is with CSR. The larger a company becomes, the more social responsibilities it will shoulder. Walton (1967) believes that CSR includes self-discipline and spontaneity. One of the indispensable elements of CSR is the transition from obligation to volunteerism.
2. Consideration of lowering negative impact based on morality, laws and economic concerns: When pursuing economic interests, companies are also shouldering legal, social and economic responsibilities. Hopfenbeck (1992) believes that, in addition to the priority of fulfilling legal responsibilities and social responsibilities, companies must also voluntarily fulfill their moral responsibilities to lower the stress and moral impact of corporate responsibilities.
3. Meeting social expectation as indicated by Davis (1960): A company has a certain level of social influence. Therefore, in the process of its decision making, its economic benefits should not be the only concern (Davis and Blomstrom, 1975). A company must protect and promote social well-being and meet society's expectation of it.

The publication of CSR reports has been regarded as an indicator of CSR commitment and implementation for companies around the world. In some countries, CSR report compilation and production has become mandatory other than voluntary. According to a KPMG survey on Top 250 companies around the world in 2008, 79% of these companies were implementing CSR, showing a 27% increase from 2005. There are totally eight major CSR standards that are relatively well-recognized around the world (see *Table 1*). They are called the "Global Eight" (McIntosh et al., 2003).



**Table 1. Eight Major International CSR Standards**

1. The OECD Guidelines for Multinational Enterprises
2. The UN Global Compact
3. The Global Sullivan Principles
4. The Global Reporting Initiative (GRI)
5. International Labor Organization, ILO
6. Social Accountability 8000 (SA 8000)
7. Account Ability 1000 (AA 1000)
8. ISO 14000

According to Roca and Searcy (2012), GRI has received more recognition than the other seven for it is currently the most widely applied. Marimon et al. (2012) indicate that GRI is applied in approximately 40% of the CSR reports around the world.

### ***Current Development of CSR***

As the connections between companies and society grow closer, there are more internal and external factors influencing companies' participation in public welfare activities. To ensure the most effective use of resources, companies often have evaluation standards on their inputs in public welfare activities. Therefore, Ballou et al. (2006) believe that CSR reports are not just intended for the interests of shareholders but for the broader interests of stakeholders.

Maher (1984) compares the amounts of pretax earnings and public welfare activity sponsorship expenses of selected companies in the US from 1972 to 1982 and finds that, despite the trend of decreasing earnings, these companies were investing more in public welfare sponsorship. Therefore, he argues that corporate sponsorship of public welfare activities is obviously no longer an act of kindness but a means of marketing. Grahn et al. (1987) further explores "the relevance of marketing purposes" to illustrate that corporate engagement in public welfare activities is intended for non-marketing purposes (such as tax reduction or social responsibility fulfillment), marketing purposes (better corporate image and visibility) or a combination of both.

The Business Council for Sustainable Development of Taiwan (BCSD-Taiwan, ROC) was established in May 1997. Composed of over 30 large companies and organizations in Taiwan as its members, it is a branch of the WBCSD. It is dedicated to promoting sustainable development of companies in Taiwan through research programs, seminars, publications, and international exchanges on issues such as international trends of related regulations and policies, environmental management, education and training, resource preservation, ecological conservation, pollution prevention and ecological benefits (Li, 2010).

### ***CSR Research***

Petrovic-Lazarevic (2008) indicates that construction companies worldwide are thinking about having their CSR initiatives with a view to enhancing their competitive advantages through better corporate images. They have gradually published reports on their charity donations and their activities of reducing pollutants, wastes, carbon emissions and energy consumption. According to Sierra et al. (2012), Spain is an international leader in terms of CSR reports.

Hernandez (2015) argues that, among contractors, developers and suppliers, contractors have the best performance in sustainable operation and development. As defined by Perrini et al. (2003), corporate sustainability refers to the ability of a company to sustain its operation for a very long period of time and this ability depends on good relationships between the company and its stakeholders. Zhao et al. (2009) indicates all the CSR guidelines and standards developed by international organizations or experts fail to include stakeholders of the company. According to Carnevale et al. (2011) and Bonsón and Bednárová (2014), there is no significant connection found between CSR disclosure levels and the company's business performance. According to existing literature, there are significant differences in the CSR disclosure indicators and disclosure levels among different industries. Waddock (2008) believe that a nation's power can have an influence on the sustainable development report levels of companies in that nation.

### ***Research Framework and Method***

This research is composed of two stages. In the first stage, secondary data from CSR reports of nine construction companies listed in the stock market and OTC market in Taiwan were collected and compared. In the second stage, an expert questionnaire survey was conducted to learn the experts' opinions about CSR and CSR implementation levels of their companies. The questionnaire survey was mainly intended to explore and compare the CSR implementation levels of selected large-sized companies in Taiwan's construction industry in terms of four dimensions: (1) corporate governance; (2) labor rights; (3) environment; and (4) social engagement. Considering the characteristics of the construction industry in Taiwan, the experts had to be working in companies each with (1) 10 or more years of operation and certain level of reputation in the industry; (2) 100 or more employees (in the case of contractors) and 50 or more employees (in the case of real-estate developers); and (3) NT\$ 1 billion or more of turnovers in at least one of the past three years. There were totally 150 companies that met these requirements. One questionnaire was sent to a manager or someone at a higher position at each of the 150 companies. In the end, totally 60 questionnaires were collected. The questionnaire results were compiled and analyzed to develop further understanding about the core issues of CSR development in each of the dimensions currently in Taiwan's construction industry. In addition, the questionnaire results were compared with the contents in the CSR reports collected in the study.

## **Research Results**

### ***Comparison of CSR Report Contents***

There are totally 69 companies in Taiwan's construction industry who are listed on the stock or OTC market. Among them, 51 (74%) are real-estate developers, eight are contractors (12%) and ten (14%) are construction material companies. There are nine of these 69 companies (13%) that have been issuing CSR reports. Six of them are contractors and the other three are real-estate developers. The company profile information of these nine companies (named respectively Company A, B, C, D, E, F, G, H and I) is listed and compared in *Table 2*. The following section is the comparison of their CSR report contents in each dimension referring to *Table 3*.

(1) *Corporate Governance*

In their CSR reports, most of the nine companies have included contents about their CSR committees, risk management committees and stakeholders. All of them have established their CSR committees except Company C and F. Company E has CSR analysis on their governance/management, environment protection and social engagement. Company D uses the technology of BIM (Building Information Modeling) to analyze their performance in environment protection and energy conservation.

**Table 2.** *Company Profile Information of the Nine Research Cases*

<b>Item</b> <b>Company</b>	<b>Type</b>	<b>Established in</b>	<b>Employee Number</b>	<b>Registered Capital (NT\$ 100 million)</b>	<b>Listed in Stock Market</b>
A	Contractor	1979	3,200	70	Yes
B	Contractor	1983	450	4.5	No
C	Contractor	1979	300	7.2	No (only OTC)
D	Contractor	1982	408	10.6	Yes
E	Contractor	1941	300	34.7	Yes
F	Contractor	1950	800	152	Yes
G	Real-estate Developer	1964	130	165	Yes
H	Real-estate Developer	1973	300	105	Yes
I	Real-estate Developer	1977	2,211	140	Yes

**Table 3.** *Comparison of Corporate Governance Dimension*

<b>Item</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>	<b>Total</b>
Establishment of CSR Committee	V	V		V	V		V	V	V	7
Establishment of Risk Management Committee	V	V	V	V	V		V	V	V	8
Sustainable Operation and Development	V	V	V	V	V	V	V	V	V	9
Stakeholder Analysis	V	V	V	V	V	V	V	V	V	9

(2) *Labor Rights*

As indicated in *Table 4*, all the nine companies provide their employees basic labor rights, welfare systems and safe working environments. In particular, Company A offers both employee club activities to bring employees closer together and good communication channels to learn more about employees' opinions. Company B employs diverse talent recruitment channels, such as industry-academia partnerships, talent recommendations by employees, job fairs on campus and online headhunting. It also has regular evaluations of its vendors. In terms of training and talent recruitment, Company B only has description in its CSR report about its training of labor health and safety without mentioning how it improves the overall professional skills of its employees. Company C is the only company that employs local people and vendors, helping to promote local development. In addition, it provides employees with opportunities of training and further education based on analyses of their conditions and requirements. It also has communication channels for its employees to express their opinions or complaints. Company E keeps records of the physical and psychological

health conditions of its employees, gives them comprehensive training and supports employee club activities helpful for their physical and mental health. Company D pays great attention to its employees' behaviors and professional ethics, provides them diverse training and development programs, holds regular educational programs of vocational safety and health management to better ensure their safety, and provides direct and open communication channels for them.

**Table 4. Comparison of Labor Rights Dimension**

Item	A	B	C	D	E	F	G	H	I	Total
Basic Rights	V	V	V	V	V	V	V	V	V	9
Welfare System	V	V	V	V	V	V	V	V	V	9
Safe Working Environment	V	V	V	V	V	V	V	V	V	9
Good Communication Channels	V		V	V			V	V	V	6
Care for Employees' Physical and Psychological Conditions				V	V		V		V	4
Training and Education	V	V	V	V	V	V	V	V	V	9
Providing Overseas Training Opportunities			V				V			2
Employee Club Activities	V				V					2
Employment of local people			V							1

### (3) Environment

As indicated in Table 5, all the nine companies seek sustainable operation through measures of energy conservation. In particular, Company A keeps daily records of its energy consumption volume, carbon emission volume and resource consumption volume. It also holds environment protection contests among its construction sites. Company B promotes natural resource conservation and adopts the 6S Policy, an innovative environment and health policy, which covers *seiri* (organization), *seiton* (neatness), *seiso* (cleaning), *seiketsu* (standardization), *shitsuke* (discipline and training) and safety. Company C applies measures such as green environment, green sourcing, environmental protection expenditure, waste reduction and pollution prevention to protect the environment. Company E uses site-specific measures to protect the environment of its construction sites. Company D conducts biodiversity surveys to protect the fauna and flora nearby its construction sites.

**Table 5. Environment Dimension Comparison**

Item	A	B	C	D	E	F	G	H	I	Total
Energy Conservation	V	V	V	V	V		V	V	V	8
Greenhouse Gas Emission Reduction	V	V	V	V	V		V	V	V	8
Use of Renewable Materials and/or Energies	V						V	V		3
Protection of Local Environment, Flora and Fauna	V	V	V	V	V		V	V		7
Waste Treatment	V	V	V	V	V	V	V	V	V	9
Water Pollution Prevention	V	V	V	V	V		V	V	V	8
Noise Prevention	V			V	V		V	V		5
Air Pollution Prevention	V	V	V	V	V		V	V	V	8

#### (4) Social Engagement

As indicated in *Table 6*, eight of the nine companies implement their social engagement through public welfare activities. Companies A, B and E also make their contributions to society by offering their professional opinions pro bono for disaster rescue work and providing evaluations of architectural structure damage for buildings in the disaster area to help ensure the security and safety of the affected residents. Companies B, C and D also forged partnerships with schools, provide opportunities for graduates-to-be to learn how to adapt to their future working environments and also reducing future personnel training costs.

**Table 6.** Comparison of the Social Engagement Dimension

Item	A	B	C	D	E	F	G	H	I	Total
Public Welfare Activities	V	V	V	V	V		V	V	V	8
Pro Bono Repair		V							V	2
Disaster Rescue and Architectural Structural Evaluation	V	V			V				V	4
Participation in Public Projects			V		V	V				3
Industry-academia Partnerships		V	V	V			V	V		5
Helping the Underprivileged	V	V		V	V		V	V	V	7
Services for Local Communities			V	V			V	V	V	5
Customer Satisfaction Survey	V	V		V			V	V	V	6

#### (5) Differences between Contractors and Real-estate Developers in CSR Implementation Dimensions

In the corporate governance dimension, the nine construction companies have comprehensive information disclosure of their internal management guidelines, systems, company conditions and governance. In the labor rights dimension, they all provide basic labor rights, employee welfare systems, education and training activities, and safe working environments. However, for the contractors, their employees mostly engage in construction activities. Therefore, they focus more on equipping their employees with knowledge about labor safety and health protection than the real-estate developers.

In the environment dimension, both the contractors and the real-estate developers focus on sustainable operation. The contractors have a direct impact on the environment and ecosystem at their construction sites. To meet the expectations of environmental protection from society, they have more comprehensive information disclosure about their greenhouse gas emission reduction and monitoring. By contrast, the real-estate developers focus more on planning and design in their business. Therefore, they have more information disclosure about use of recycled and/or environmental friendly materials, evaluations of the environment, fauna and flora at the construction sites before construction, and green/smart buildings.

In the social engagement dimension, the contractors and the real-estate developers mainly focus on public welfare/charity activities and helping the underprivileged. In particular, some of the contractors provide pro bono evaluations of building structures after disasters and assist with disaster rescue work by providing their professional knowledge and technology. This kind of social engagement can help to improve their corporate images. The real-estate developers mainly improve their images and make their contributions to society through educational/cultural activities and local community services.

### ***Analysis of CSR Implementation Levels in Taiwan's Construction Industry***

Table 7 lists the corporate profile information of the subjects in the questionnaire survey of this study. Among them, ten (16.7) have established their CSR committees, six (10%) have planned their CSR committee establishment and are implementing their plans, ten (16.7%) have planned their CSR committee establishment but are not implementing their plans. Among these companies, 34 (56.7%) have not established CSR committees yet and only nine (22.5%) have plans to establish CSR committees. This finding reflects that most of the companies in the construction industry have not fully implemented CSR in Taiwan.

**Table 7.** Corporate Profile Information of the Questionnaire Survey Subjects

<b>Category</b>	<b>Item</b>	<b>Number</b>	<b>Ratio</b>
Company Type	Contractor	30	50.0%
	Real-estate Developer	30	50.0%
Establishment of CSR Committee	Yes	10	16.7%
	Planned and being implemented	6	10.0%
	Planned but not implemented	10	16.7%
	No Plan	34	56.7%
Registered Capital (NT\$ billion)	0.1~<0.2	12	20.0%
	0.2~<1	18	30.0%
	1~<4	18	30.0%
	>4	12	20.0%
Turnover Last Year (NT\$ billion)	1<3	20	33.3%
	3~<6	13	21.7%
	6~<10	14	23.3%
	>10	13	21.7%
Number of Employees	50~<100	28	46.7%
	10~<200	9	15.0%
	201~<400	9	15.0%
	>400	14	23.3%
Company Age	10~<20 Years	16	26.7%
	20~<30 Years	17	28.3%
	30~<40 Years	14	23.3%
	>40 Years	13	21.7%
CSR Report Issuance	Yes	7	11.7%
	No but Report under Production	9	15.0%
	No but Preparing	9	15.0%
	No Plan	35	58.3%
Listed on the Stock/OTC Market	Yes	24	40.0%
	No	36	60.0%
Overseas Branch/Investment	Yes	19	31.7%
	No	41	68.3%
Major Clients	Governmental Organizations	6	10.0%
	Private Entities	42	70.0%
	Both	12	20.0%

As indicated in Table 8, among those companies with over 200 employees, seven (30.7%) have established their CSR committees, higher than the 8.1% among the companies with less than 200 employees. This finding indicates that, with more employees, a company will have more sufficient human resources and more willingness to establish its CSR committee.

**Table 8.** Number of Employees and Establishment of CSR Committee

		CSR Committee Establishment				Total
		Established	Planned and Implementing	Planned but Not Implemented	No Plan	
Number of Employees	<200	3	4	6	24	37
		8.1%	10.8%	16.2%	64.9%	100.0%
	>200	7	2	4	10	23
		30.4%	8.7%	17.4%	43.5%	100.0%
Total		10	6	10	34	60
		16.7%	10.0%	16.7%	56.7%	100.0%

According to *Table 9*, ten (20.4%) of the companies with registered capital of over NT\$1 billion each have established their CSR committees. Among the eleven companies each with registered capital of less than NT\$1 billion, eight (72.7%) have no plan of CSR committee establishment, compared with 26 companies (53.1%) that have no plan of CSR establishment among the 49 companies each with registered capital of over NT\$1 billion. This finding reflects that larger companies with more registered capital have more resources for CSR committee establishment.

**Table 9.** Registered Capital and CSR Committee Establishment

		CSR Committee Establishment				Total
		Established	Planned and Implementing	Planned but not Implemented	No Plan	
Registered Capital	<NT\$1 Billion	0	1	2	8	11
		0.0%	9.1%	18.2%	72.7%	100.0%
	>NT\$1 Billion	10	5	8	26	49
		20.4%	10.2%	16.3%	53.1%	100.0%
Total		10	6	10	34	60
		16.7%	10.0%	16.7%	56.7%	100.0%

As indicated in *Table 10*, the contractors and the real-estate developers in this study are not significantly different in their CSR implementation levels. Among the corporate samples in this study, five contractors and two real-estate developers issued CSR reports this year, compared with three real-estate developers and six contractors in 2015 and only two contractors in 2014. Even though this finding reflects a growing number of companies in the construction industry that have issued their CSR reports, the CSR report issuance in the construction industry is increasing slowly.

**Table 10.** Comparison of Contractors and Real-estate Developers in CSR Implementation Dimensions

Dimension	Company Type	Average	Difference	t	Significance
Corporate Governance	Contractor	4.44	0.08	0.30	0.78
	Real-estate Developer	4.36			
Labor Rights	Contractor	5.02	0.26	1.09	0.28
	Real-estate Developer	4.76			

Environment	Contractor	4.59	-0.34	-1.46	0.15
	<i>Real-estate Developer</i>	4.93			
Social Engagement	Contractor	4.41	-0.09	-0.37	0.76
	<i>Real-estate Developer</i>	4.50			

## Conclusion and Suggestion

### *CSR Implementation of Large-sized Companies in the Construction Industry*

The CSR reports of large-sized companies in Taiwan's construction industry contain relatively comprehensive information about their CSR implementation. By contrast, those companies that have not issued CSR reports only regard CSR as simply giving back to society and only implement CSR when they are making profits without much consideration about sustainable development. Among those companies in this research that are willing to establish or have established their CSR committees, 54.3% are traded on the stock/OTC market, 72.7% are companies with a history of over 30 years each, 72% are companies with registered capital of over NT\$1 billion each, and 72% are companies with over 200 employees each. This finding indicates that larger companies in Taiwan's construction industry have higher willingness to establish CSR committees.

Except for the companies that have issued CSR reports, those companies interested in CSR implementation or even CSR report issuance are mainly driven by one or more of the following three reasons: (1) transformation into a company of bigger size and scale; (2) plan to be listed in the stock/OTC market; and (3) expanding overseas business.

In addition, according to the CSR report analysis results of this study, the contractors and the real-estate developers are not significantly in their CSR implementation levels. However, they are mainly different in the CSR dimensions they focus on. The contractors pay more attention to their environmental influence, carbon emissions and impact on biodiversity at their construction sites. By contrast, the real-estate developers focus more on the pre-construction environmental evaluations and energy-saving designs.

### *Suggestions of CSR Targets for Companies*

Based on the CSR reports collected in this study and the questionnaire results analysis findings, easy-to-reach targets in each of the following four CSR dimensions are suggested as follows:

#### *(1) Corporate Governance*

CSR committee establishment: CSR implementation must start from the high-level leadership at the company. The establishment of a dedicated organization at the high-level will significantly help to promote all the CSR projects. This organization will help to ensure top-down CSR implementation to achieve maximum results.

#### *(2) Labor Rights (GRI G4-LA1~LA16)*

To provide employees with a good working environment, welfare system, education and training activities, good communication channels, and knowledge about labor safety



and health. CSR implementation also requires efforts and collaboration from employees at the bottom; therefore, it is very important to give employees a safe, healthy and encouraging environment.

(3) *Environment (GRI G4-NE15~NE21, EN34)*

Real-estate developers are suggested to conduct pre-construction environmental evaluations of the construction sites, select environmentally friendly materials for architecture design, and/or design/build green buildings. Contractors are suggested to pay attention to their pollution and carbon emissions during the construction process and select construction techniques suitable for each construction site to reduce their impact on local environment.

(4) *Social Engagement (GRI G4-SO1~SO5)*

Strengthening connections with schools: It is found in this study that CSR implementation in Taiwan's construction industry is relatively weak in terms of connections with schools. Measures such as providing scholarships, internships or work-study opportunities and industry-academia partnerships are suggested to not only recruit future talent but also improve the corporate image.

**Acknowledgements.** We gratefully acknowledged the financial support (NSC 100-2221-E-151-050-) from Taiwan's Ministry of Science and Technology.

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# APPLICATION OF A NOVEL FORMALDEHYDE SENSOR WITH MEMS (MICRO ELECTRO MECHANICAL SYSTEMS) IN INDOOR AIR QUALITY TEST AND IMPROVEMENT IN MEDICAL SPACES

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** In the indoor air environment in Taiwan, formaldehyde concentration stays at a high level, which is an important issue affecting indoor air quality, and the formaldehyde issue in medical building spaces is more severe. The novel formaldehyde sensor based on microelectromechanical systems (MEMS), which uses quartz glass as basic material, platinum as micro heater resistance, as well as a heat sensing layer and NiO film as a sensing layer. NiO film was used to form a sensing layer in the method of sputter deposition. Platinum was used as electrode to measure and sense resistance change. When there was formaldehyde gas in the environment, the electrical conductivity on the NiO film increased, thus causing the resistance on the sensing layer to decrease. The sensor displayed the value of formaldehyde concentration. The novel formaldehyde sensor with MEMS was applied and tested in a large medical center (medical space) in southern Taiwan. The formaldehyde concentration in 120 points in one medical building was tested. The results showed that the indoor formaldehyde concentration was between 0.01-2.31 ppm, exceeding the indoor air quality standard - 0.08 ppm, and the failure rate of the whole building was over 50%.

**Keywords:** *healthy environment, exposure assessment, cancer risk, building materials, plasma*

## Introduction

Taiwan is located in a humid subtropical region. Intensive development and environmental pollution can affect indoor environmental quality (Chiang et al., 1996), and indoor air pollution in particular can harm health and re-duce comfort and safety. The problems with indoor environment pollution are especially severe in developed countries located in temperate regions. Existing buildings currently take up 97% of total buildings. The functions of Existing buildings de-cline as they approach the end of their cycles; dis-eases such as sick building syndrome (SBS), sick house syndrome (SHS), building related illness (BRI) (Molhave and Thorsen, 1991; Molhave, 2003; Wolkoff and Nielsen, 2001; Wieslander et al., 1997). Sick buildings and sick houses often develop during the “completion of new construction” or “renovation of building construction” stages (WHO, 1989; EURO, 2006; Jarnstrom et al., 2006). Studies on sick houses and buildings in taiwan show exceeding levels of methanol hazardous to health;

the risk of cancer development by methanol is 100~1000 times greater than that of cancers caused by other mean (Wu et al., 2003, 2005).

Taiwan is located in the subtropical climate region. It is hot and humid on summer, in addition to the cold and humidity winter have significant effects in medical buildings. The medical space in southern Taiwan are renovate with large amount of building materials in indoor, which causes formaldehyde and VOCs emissions from these indoor building materials to accumulate inside. (Wolkoff et al., 1998, 2003) Although Green Building Materials Labels provide a category for Low-Emission Materials in Taiwan, but the labels are only for encouragement purposes and are rarely being used. In a hot and humid environment with low ventilation, Sick House Syndrome (SHS) or Multi-Chemicals sensitivity (MCS) (WHO., 2000, 2001) to chemical sub-stances often affect medical patient (*Figures 1 and 2*).



**Figure 1.** *The interior equipment of medical space in southern taiwan*



**Figure 2.** *The indoor environment of medical space in southern taiwan*

## Literature Review

### *The Indoor Air Quality Management Act in Taiwan*

The indoor air quality management act which would test and manage the indoor air quality, With the legislative passing of the Indoor Air Quality Management Act, Taiwan joined South Korea and become the second nation in the world to enact a law regulating indoor air quality. The air quality management act targets public areas, such as schools, cram schools, medical and government organizations, financial institutions, opera houses, hotels, post offices as well as public transportation platforms. Particular air quality requirements are given to different premises depending on their size, area, and exposure. The Environmental Protection Administration (EPA) and other environmental agencies can conduct unscheduled inspections, testing for excessive levels of CO<sub>2</sub>, VOCs, formaldehyde, TVOC, bacteria, fungi and other airborne pollutants.

### *A Novel Formaldehyde Sensor with MEMS (Micro Electro Mechanical Systems) for indoor air quality test*

A novel micro-fabricated formaldehyde gas sensor with an integrated micro-hotplate (Lee et al., 2006). A new fabrication process has been developed for the formaldehyde gas sensor with a self-heating NiO thin film. The NiO thin film is deposited on the microstructure, and Pt metal resistors are deposited as micro-heaters. Au IDEs are formed to measure the conductivity change caused by formaldehyde oxidation at the

oxide surface. Not only can the high stability, the low hysteresis value and a quick response time be attained for the proposed MEMS-based sensor, but decreasing the grain size of the oxide sensor material in the sputtering process also significantly increases the sensitivity of the gas sensor ( $0.14 \Omega\text{ppm}^{-1}$ ) and improves its detection limit capability (1.2 ppm). The integrated micro hotplate simplifies the experimental set-up and can be realized using a simple fabrication process. The present micro-fabricated formaldehyde gas sensor with a self-heating NiO thin film is suitable not only for industrial process monitoring, but also for the detection of formaldehyde concentrations in buildings in order to safeguard human health.

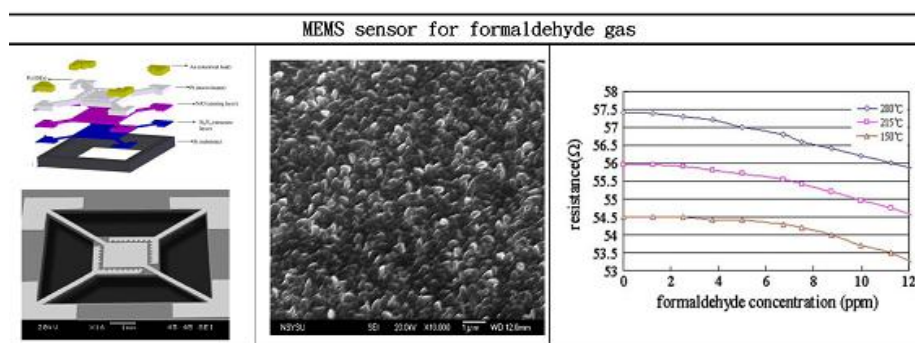
## Methodology

### Research methods

This study developed a novel formaldehyde sensor based on microelectromechanical systems (MEMS), which uses quartz glass as basic material, platinum as micro heater resistance, as well as a heat sensing layer and NiO film as a sensing layer. NiO film was used to form a sensing layer in the method of sputter deposition. Platinum was used as electrode to measure and sense resistance change. When there was formaldehyde gas in the environment, the electrical conductivity on the NiO film increased, thus causing the resistance on the sensing layer to decrease. The sensor displayed the value of formaldehyde concentration (*Table 1*).

The methods of detection for formaldehyde gas may be divided into three main categories: Gas chromatography–mass spectrometry (GC/MS), optical detection devices, and Micro Electro Mechanical Systems (MEMS) based gas sensors. Gas chromatography mass spectrometry (GC/MS) is a method that combines the features of gas–liquid chromatography and mass spectrometry to identify different substances within a test sample. Although it provides high sensitivity and selectivity, the drawbacks of high preventive costs and ponderous uses cannot be ignored. Numerous researchers have studied optical sensor with formaldehyde quantification applications. Even though the optical sensors are capable of simultaneous samplings and have instantaneous analyzing time, the associated optical arrangements tend to be rather bulky and elaborate. In the last decade, emerging MEMS and micro-machining techniques have led to the development of miniaturized sensing instrumentation that is capable of accessing information at a micro scale level. Most important, the functionality and reliability of these micro sensors can be increased through their integration with mature, logic IC technology or with other sensors.

**Table 1.** The MEMS sensor test for formaldehyde gas



### *The IAQ sampling plan in medical space*

The medical space was a large building (the total floor is 12F). The formaldehyde concentration in 120 points in one medical building was tested.

According to the indoor air quality management act (*Table 2*). The amount of indoor air sampling point have be provide. Each floor had to be calculate by floor area (*Table 3*).

*Table 2. The sampling point per area*

Floor Area (A) m <sup>2</sup>	Sampling point
$A \leq 5000$	$S \geq 1$
$15000 \geq A > 5000$	$S \geq 2$
$30000 \geq A > 15000$	$S \geq 3$
$A > 30000$	$S \geq 4$

*Table 3. The sampling point plan in medical spaces*




floor	Sampling points	Sampling time
1 <sup>st</sup> FLOOR	10	24hr
2 <sup>nd</sup> FLOOR	20	1hr-8 hr
3 <sup>rd</sup> FLOOR	5	1hr-8 hr
4 <sup>th</sup> FLOOR	10	1hr-8 hr
5 <sup>th</sup> FLOOR	10	1hr-8 hr
6 <sup>th</sup> FLOOR	10	1hr-8 hr
7 <sup>th</sup> FLOOR	10	1hr-8 hr
8 <sup>th</sup> FLOOR	10	1hr-8 hr
9 <sup>th</sup> FLOOR	10	1hr-8 hr
10 <sup>th</sup> FLOOR	10	1hr-8 hr
11 <sup>th</sup> FLOOR	10	1hr-8 hr
12 <sup>th</sup> FLOOR	5	1hr-8 hr

### *IAQ screen test and methods*

The IAQ experiment test method based on the ISO 16000-1,2. Screening test methods (*Table 4*) are of the type which can quickly provide an indication of the air pollution present without using expensive analy-sis techniques. The result can inform a decision on the extent of further required measurements. When using screening tests, the basic demands of the measuring strategy have to be considered in this case.

The diffusive sampling method for formaldehyde is suitable for measurements in atmospheres of up to relative humidity and for monitoring at air velocities as low as . Potential interferences, including those due to the presence of other carbonyl compounds, should be eliminated by the chromatographic step in the method. The sampling method gives a time-weighted average result. This test method is applicable to the measurement of formaldehyde) in indoor air over the range from 0.001 mg/m<sup>3</sup> to 1 mg/m<sup>3</sup> for a sampling period of between 24hr and 72hr .

**Table 4.** The IAQ screen test and methods

MEMS Sensor	diffusive sampling	24hr Sampling
		

## Research Results

### Formaldehyde concentration in medical space

The novel formaldehyde sensor with MEMS was applied and tested in a large medical center (medical space) in southern Taiwan. The formaldehyde concentration in 120 points in one medical building was tested. The results showed that the indoor formaldehyde concentration was between 0.01-2.31 ppm (Table 5), exceeding the indoor air quality standard - 0.08 ppm, and the failure rate of the whole building was over 50%. Moreover, indoor air quality was improved in the areas with a relatively high formaldehyde concentration (dental rooms) by adopting the plasma formaldehyde removing technology in the indoor air conditioning system. Under the 10-day formaldehyde control with the plasma formaldehyde removing technology, the indoor formaldehyde concentration reduced from 1.32ppm to 0.95ppm (Figure 3).

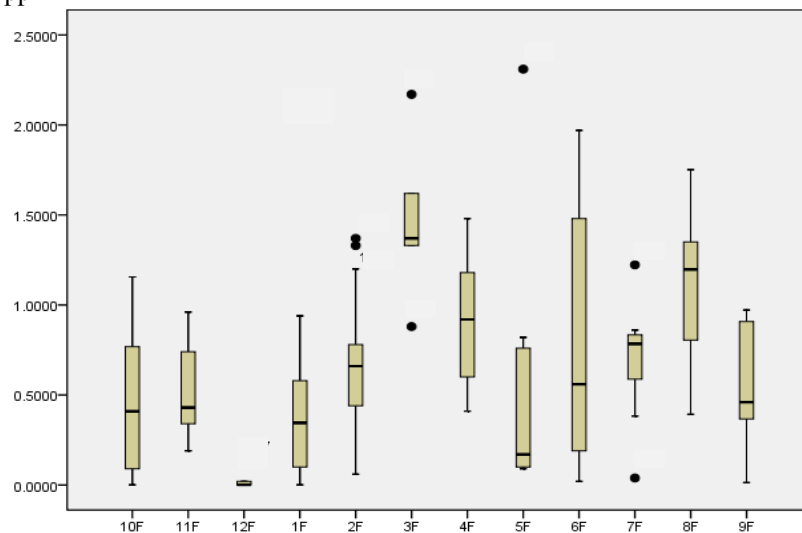
Seen from the results sampled from 6 monitoring spaces which are under continuous monitoring for 24h by novel formaldehyde sensor with MEMS, diachronic changes of formaldehyde in 24h all exceed 0.08ppm reference value, with an average concentration of 0.22ppm (Figure 4). Concentration of formaldehyde reduces only at 7:00am since the air conditioners are shut down, that at the other time periods are all higher than the healthy reference value. This indicates that the indoor environment is polluted seriously by formaldehyde and concentration of in-door formaldehyde is affected directly by air-conditioning system.

**Table 5.** The formaldehyde concentration in medical space

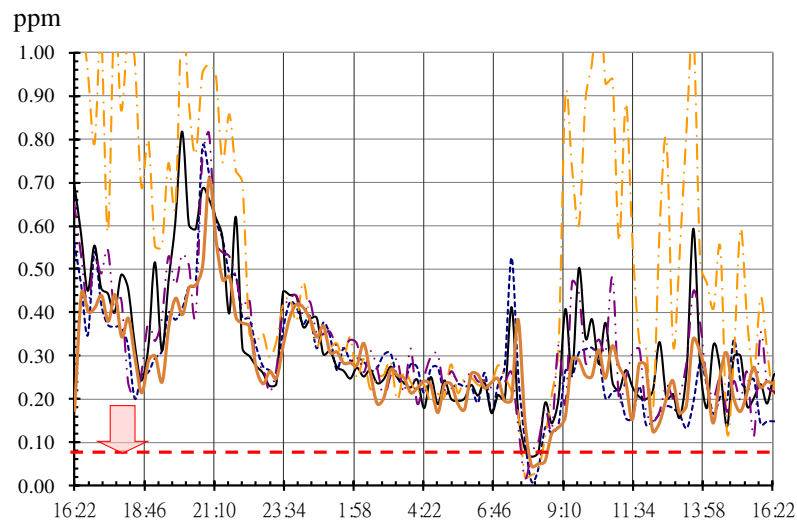
floor	Ave. ppm	Max. ppm	Min. ppm
1 <sup>st</sup> FLOOR	0.513	2.09	0.001
2 <sup>nd</sup> FLOOR	0.648	1.37	0.06
3 <sup>rd</sup> FLOOR	1.474	2.17	0.88
4 <sup>th</sup> FLOOR	0.898	1.48	0.41
5 <sup>th</sup> FLOOR	0.541	2.31	0.09
6 <sup>th</sup> FLOOR	0.83	1.97	0.02
7 <sup>th</sup> FLOOR	0.702	1.22	0.03
8 <sup>th</sup> FLOOR	1.09	1.75	0.3
9 <sup>th</sup> FLOOR	0.547	0.97	0.01
10 <sup>th</sup> FLOOR	0.432	1.1	0.001
11 <sup>th</sup> FLOOR	0.535	0.96	0.19



floor	Ave. ppm	Max. ppm	Min. ppm
12 <sup>th</sup> FLOOR	0.031	0.13	0.001



**Figure 3.** The formaldehyde concentration in different floor



**Figure 4.** The 24hr sampling on formaldehyde concentration in medical space

Dynamic changes of indoor CO<sub>2</sub> are compared, as seen, concentration of formaldehyde increases in the area with higher CO<sub>2</sub> concentration. It is the problem of formaldehyde accumulation due to poor ventilation of air conditioner. Improvement by means of ventilation and dilution: pollutants are removed in the way of increasing fresh external air amount and raising the fresh external air ratio to improve the indoor air quality.

### ***The dissusive formaldehyde flux from materials***

Passive formaldehyde sensing patch is used in indoor decoration materials through pollution source identification technology. Seen from the results, formaldehyde

emission rate for indoor building materials is 2 times higher than green building materials (Table 6). This indicated that indoor building materials emit formaldehyde in the long term and absorb formaldehyde in the air to become the pollution source.

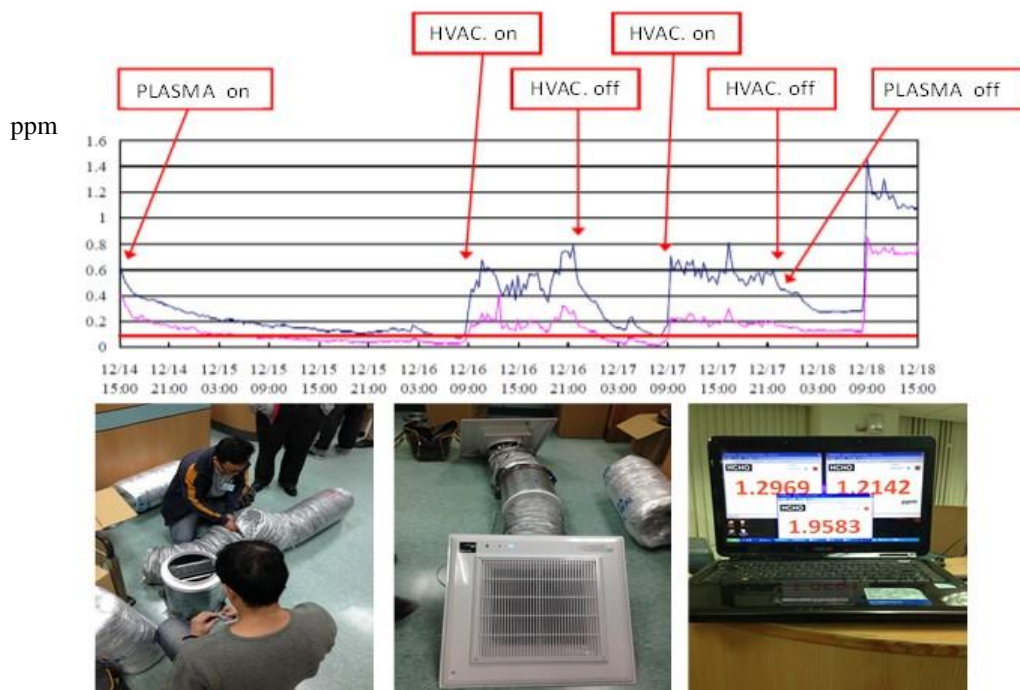
**Table 6.** The dissusive formaldehyde flux from materials

Sample NO.	dissusive formaldehyde flux
1	0.146 mg/m <sup>2</sup> *hr
2	0.157 mg/m <sup>2</sup> *hr
3	0.136 mg/m <sup>2</sup> *hr



**The plasma formaldehyde removing technology**

Plasma formaldehyde-removal technology is used in indoor air-conditioning system to remove the pollutants and improve indoor air quality. Indicated by the results, indoor formaldehyde pollutants can be decomposed and removed effectively. the plasma formaldehyde removing technology in the indoor air conditioning system. Under the 10 day formaldehyde control with the plasma formaldehyde removing technology, the indoor formaldehyde concentration reduced from 1.32ppm to 0.95ppm (Figure 5).



*Figure 5. The plasma formaldehyde removing technology*

## Conclusion

This study developed a novel formaldehyde sensor based on microelectromechanical systems (MEMS), which uses quartz glass as basic material, platinum as micro heater resistance, as well as a heat sensing layer and NiO film as a sensing layer. NiO film was used to form a sensing layer in the method of sputter deposition. Platinum was used as electrode to measure and sense resistance change. When there was formaldehyde gas in the environment, the electrical conductivity on the NiO film increased, thus causing the resistance on the sensing layer to decrease. The sensor displayed the value of formaldehyde concentration.

The novel formaldehyde sensor with MEMS was applied and tested in a large medical center (medical space) in southern Taiwan. The formaldehyde concentration in 120 points in one medical building was tested. The results showed that the indoor formaldehyde concentration was between 0.01-2.31 ppm, exceeding the indoor air quality standard - 0.08 ppm, and the failure rate of the whole building was over 50%. Moreover, indoor air quality was improved in the areas with a relatively high formaldehyde concentration (dental rooms) by adopting the plasma formaldehyde removing technology in the indoor air conditioning system. Under the 10-day formaldehyde control with the plasma formaldehyde removing technology, the indoor formaldehyde concentration reduced from 1.32ppm to 0.95ppm.

Although it was not reduced to the indoor air quality standard value, the results showed that the method can effectively dissolve indoor formaldehyde. The novel formaldehyde sensor with MEMS can be widely used to test and improve indoor air quality, and can be combined with intelligent monitoring systems and intelligent air conditioning and ventilating equipment in future, to maintain indoor air quality and effectively ventilate the space. The research achievement can be popularized to industry for immediate application.

**Acknowledgements.** This research is supported by the research program MOST 103-2221-E-272-003 and 103-2221-E-006-148 from the Ministry of Science and Technology, Taiwan.

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# AN EMPIRICAL STUDY ON THE EFFECT OF ECO-TOURISM VISITORS' ENVIRONMENTAL ATTITUDES ON ENVIRONMENTAL BEHAVIOR

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(Received 19<sup>th</sup> Sep 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** Eco-tourism, a tourism business emerged in the end of 20<sup>th</sup> century, covers the education awareness of environmental conservation. Without quality environment, visitors would not actively go sightseeing. For this reason, sightseeing, to some degree, is attached to the environment. Domestic and international public sectors and private sectors therefore discuss eco-tourism related issues, think of reducing the impact of eco-tourism on the environment, and maintain the right to enjoy natural resources and the environment for descendants. Visitors to Yongchun Niumulun Ecological Tourism Zone, the research object in this study, are distributed and collected the questionnaire on-site. Total 360 copies of the questionnaire are distributed, and 251 valid copies are retrieved, with the retrieval rate 70%. The research results are summarized as following. 1. Environmental attitudes present significant correlations with tourist satisfaction. 2. Tourist satisfaction shows remarkable correlations with environmental behavior. 3. Environmental attitudes reveal notable correlations with environmental behavior. The suggestion, proposed according to the research result in this study, expects to reduce the impact of eco-tourism on the environment and maintain the rights to enjoy natural resources and the environment for descendants.

**Keywords:** *persuasive action, environmental ethics, ecological management, characteristics, satisfaction*

## Introduction

In past years, changes of economic patterns, living habits, two-day weekend, and the increase in national income in Taiwan have the people stress on sightseeing and recreation activity after satisfying the material life. The expense on sightseeing and recreation activity is also increased to satisfy the spiritual and psychological life. Moreover, active promotion of domestic travel by the government, convenient transportation, and the promotion and introduction of mass media have recreation become an essential part of life. With narrow land and dense population, crowded and busy urban life and inadequate recreation space and facilities in Taiwan have the public desire to return to the countryside and be close to the nature. Because of the popularity of environmental awareness, the advance of conservation zone management and the change in consumer markets, a travel pattern different from traditional mass tourism but combining recreation activity with ecological conservation, environmental education, and cultural experience, are generated, called eco-tourism. Sightseeing activity is called “an industry without chimney” as it is regarded as an industry without pollution. The environment is the basis of sightseeing; without quality environment, few visitors would actively go sightseeing. In this case, sightseeing, to some extent, is attached to the

environment. Eco-tourism awareness is rising in past years. Being a tourism business emerged in the end of 20<sup>th</sup> century, eco-tourism results in threats to the environment in the next century. Eco-tourism related issues are therefore discussed domestically and internationally, thinking of reducing the impact of eco-tourism on the environment and maintaining the right to enjoy natural resources and the environment for descendants.

## Literature and hypothesis

### *Environmental attitudes*

Maulidya et al. (2014) pointed out attitudes as a persistent and consistent tendency towards people, affairs, and the surrounding world. Hanington and Martin (2012) regarded attitudes as an inner psychological idea acquired through oral reports and behavior observation; and, attitudes was specified through individual introspection. As a matter of fact, attitudes stand for the persistent emotion and belief learned by certain objects, and such emotion and belief have people who have such attitudes present specific behavior towards such objects, relating to understanding, evaluating, and predicting individual behavior. In other words, attitudes are individual positive or negative evaluation towards certain behaviors, relating to belief. Satyanarayana et al. (2012) regarded the environment as whatever could stimulate, affect, or induce individual and group behavior, referring to visitors' travel destinations as the object formed by eco-tourism environmental attitudes. It presented the relative relationship between a subject (visitors) and an object (the environment). In this case, environmental attitudes could be defined as the belief composition of special situations in the environment, the entire environment or the people or objects directly related to the environment. Such composition contained the overall evaluation of for or against and preference or aversion. The "environmental attitudes towards eco-tourism" is defined as visitors' attitudes towards the travel environment, including cognition, emotion, and intention.

Husted et al. (2014) indicated that environmental attitudes should focus on environmental ethics, including natural resources, environment development, environment protection, ecological relationship, and environmental responsibility. Furthermore, the structure of New Environment Paradigm (NEP) was to challenge the idea of protecting the environment with tradition and covered three new norms of (1) believing in human ability to destroy the environment, (2) restricted growth, and (3) proper rules to restrict human behavior in the nature (Cheung et al., 2014). Such a theory also conforms to the spirit of eco-tourism. Referring to Hsiao and Ou (1998), environmental attitudes towards eco-tourism in this study combine the idea of NEP and the definition of eco-tourism to deduce the dimensions of environmental ethics, environmental education, and environmental resources.

(1) Environmental ethics: Environmental ethics of eco-tourism explains the moral subject of "ecology centered" that it does not simply cherish and respect natural resources, but considers, under the entire natural value and responsibility, to think based on ecology, to combine science and ethics, and to promote the concern to biomass, and even non-biomass, including human beings, animals and plants, rivers, and natural landscape. Such a spirit is the basic respect and concern about the nature as well as the ignorable attitudes towards the environment in tourism.

- (2) Environmental education: Environmental education aims to cultivate environment responsible citizens who present perception and sensitivity on the environment and environment related issues and show basic knowledge of the environment and the problem. Environmental education therefore would be a major content of eco-tourism, allowing visitors to have different experiences in eco-tourism and powerfully persuading visitors to participate in environment conservation (Zsóka et al., 2013).
- (3) Environmental resources: “Sustainable development” is the guideline in eco-tourism. In addition to satisfying visitors' self-satisfaction and sense of experience in the travel, it also avoids the unrecovered impact of travel on the environment. As a result, sustainable development, based on stable ecological systems, stresses on biodiversity, develops the quality satisfying human life, and establishes the balance between “demand” and “restriction” for the environment and resources.

### ***Tourist satisfaction***

Chiu et al. (2014) stated that “satisfaction”, as a useful measuring indicator, used to be used for measuring people's opinions about products, work, quality of life, communities, or outdoor recreation quality. However, customer satisfaction still requires diverse discussions as everyone has distinct personal traits and socio-economic background and appears diverse attitudes, preference, and motivation about the same object. Nunkoo and Ramkissoon (2011) considered that customer satisfaction, as the emotional or cognitive judgment according to the background at the time, was positively affected by emotion and cognition. Ahmed et al. (2015) measured and evaluated customer satisfaction with retail stores and proposed that satisfaction was the service quality being different from the satisfaction level in the product acquisition or consumption process; service quality was customers' continuous evaluation of affairs, while satisfaction level was the temporary emotional reaction towards affairs. Senyolo et al. (2014) also thought that consumer satisfaction could be regarded as an overall evaluation reaction, which stood for consumers' subjective reaction to products with different attributes. Jung et al. (2015) pointed out consumer satisfaction as the overall perception, which could be directly evaluated, of like after the consumption. Buckley et al. (2012) regarded customer satisfaction as individual satisfaction from the comparison of product performance cognition and personal product expectation. Satisfaction level was the difference function between perceived performance and expectation. Teksoz et al. (2012) indicated that consumers would express personal feelings about the use of products with emotional words and generate the emotions of satisfaction or dissatisfaction. Regarding the rational cognition evaluation, Kang et al. (2012) studied consumer behavior and proposed that satisfaction was the cognition of consumers purchasing certain products by judging the acquired reward and compensation being proper for the sacrifice.

Referring to *Planning and Management of Sightseeing and Recreation Areas* written by Kang et al. (2012), 1.characteristics, including uniqueness, appreciation, originality, experience, and history and 2.development potential, containing served population, accessibility, quality, and management are the evaluation standards of tourist satisfaction in eco-tourism.

### ***Environmental behavior***

Environmental behavior studies “the interaction between humans and the environment” (Chaminuka et al., 2012). De Gusmão Pedrini et al. (2015) proposed the broad and narrow explanation of behavior in psychology. Narrow behaviors referred to individual “explicit motions”, such as walking, working, and running. Such motions could be directly observed by others' senses or recorded by videos and cameras; and, the analyzed and processed “activity” was behavior. In addition to explicit motions, broad behavior was defined as inner psychology, like motivation, thinking, awareness, belief, and value, which were the drive of explicit behavior and presented the possibility and tendency to determine the behavior. Bauer (2012) pointed out the necessity of citizens, after having knowledge, attitudes, and skills, taking actions to participate in solving various environmental problems. Such behavioral intention or results should be compatible with the natural ecological process. In the discussion of visitor reaction towards the environment, Lemes et al. (2014) included behavior in explicit motions to avoid visitors' psychological factors in the complicated relationship between attitudes and behavior.

Referring to Lo and Jim (2015), the dimensions of environmental behavior contain the following.

1. Persuasive action, referring to force people taking positive environmental behavior with speech. Persuasion could change people's belief or value, such as discussion, debate, speech, comment in newspaper and magazine, and guided education activity.
2. Consumption action, referring to the economic threats or action taken by individuals or groups to change certain commercial or industrial behavior, such as refusing to buy products with impact on the environment, processed food, or food packed with too much plastic.
3. Ecological management, referring to actual action taken by individuals or groups to maintain or enhance current ecological systems, such as reforestation, recycle, and conservation of energy.
4. Legal action, referring to individuals, groups, or organizations taking legal action, aiming at reinforcing or modifying environment regulations or banning certain behavior, to solve environmental problems, such as accusation, warning, and court injunction.

### ***Research hypothesis***

When studying environmental behavior, researchers discovered several factors in environmental behavior. Besides, literatures indicated that the correlation between specific environmental attitudes and behavior was more important than general attitudes as specific attitudes could predict relevant environmental behavior (Damodaran, 2014). Knowledge, attitudes, and responsible environmental behavior showed positive correlations, revealing that people with more knowledge or active attitudes would better engage in responsible environmental behavior (Ke, 2012). Besides, an individual with responsibility for the environment or oral commitment to the environment would be more willing to precede environmental behavior (Shen, 2013). Researchers discussed the relationship between environmental behavior and various factors and discovered that ones with positive environmental attitudes would not necessarily practice conservation behavior actively (Ramdas and Mohamed, 2014). Nevertheless, researchers discovered,



in the research on factors in responsible environmental behavior, that individuals with more positive attitudes towards environmental issues would present higher responsible environmental behavior (Cheung et al., 2014). With New Environment Paradigm Scale and Responsible Environmental Behavior Scale, researchers measured the environmental concept and the intention to take responsible environmental behavior of the freshmen in normal universities and discussed the relationship between the two. It was found that the freshmen in normal universities with higher support of New Environment Paradigm Scale would have higher intention to take responsible environmental behavior (Zhou et al., 2013). The following hypothesis is therefore established in this study.

H1: Environmental attitudes present significant correlations with tourist satisfaction.

Researchers indicated that visitors would induce positive emotion after experiencing eco-tourism, and the satisfaction and environmental behavior would appear positive effects (Reimer and Walter, 2013). In the research on visitors to Yangmingshan National Park, Shrode (2012) pointed out the positive correlation between tourist satisfaction and environmental behavior, and visitors with higher tourist satisfaction presented higher environmental behavior. Ly and Bauer (2014) indicated that visitors with higher tourist satisfaction showed higher responsible environmental behavior. A study on Penghu, Taiwan, also proposed that tourists with higher satisfaction showed higher environmental behavior, with positive correlations (Wu, 2012). However, it is considered in this study that users with high satisfaction would have the idea of “love me, love my dog” so that they could perform positive environmental behavior. The following hypothesis is therefore established in this study.

H2: Tourist satisfaction shows remarkable correlations with environmental behavior.

Samdin et al. (2013) discovered that consumers highly concerning about the environment appeared higher support of eco-tourism, intention to choose eco-tourism, and satisfaction. Lu and Stepchenkova (2012) stated that visitors' attitudes towards eco-tourism could predict the behavior during or after the travel; visitors with more positive environmental attitudes and better agreement with the environment management strategy were more easily sensitive to environmental issues and willing to participate in relevant conservation action. Visitors with incorrect attitudes and concepts about environmental resources, on the other hand, did not respect the environment and were not willing to conform to the regulations or appeared low satisfaction. Consumers with stronger motivation of eco-tourism would reinforce the relationship between eco-tourism information and attitudes. Consumers with strong environmental attitudes would collect eco-tourism information, or those with good perception might show stronger satisfaction. The following hypothesis is further established in this study.

H3: Environmental attitudes reveal notable correlations with environmental behavior.

## **Method and research object**

### ***Research object***

Visitors to Yongchun Niumulin Ecological Tourism Zone, as the research object, are distributed and collected the questionnaire on-site. A total of 360 copies of the

questionnaire are distributed and 251 valid copies are collected, with the retrieval rate 70%. Yongchun Niumulin Ecological Tourism Zone, with the good name of “Minnan Xishuangbanna”, has the original forest groups which are best conserved in southern Fujian areas and show the best characteristics. Located in Xiayang Township, Yongchun County, Quanzhou City, it is a national AAAA level tourist attraction and provincial natural reserve as well as the ecological education base and science education base in Fujian Province.

**Analysis method**

Regression Analysis is applied to understand the relationship among environmental attitudes, tourist satisfaction, and environmental behavior.

**Analysis result**

**Reliability and validity analysis**

With Factor Analysis, environmental attitudes in this study is extracted three factors of “environmental ethics” (eigenvalue=3.762,  $\alpha=0.83$ ), “environmental education” (eigenvalue=2.831,  $\alpha=0.86$ ), and “environmental resources” (eigenvalue=2.475,  $\alpha=0.81$ ). The accumulated covariance explained achieves 83.762%.

Tourist satisfaction, with Factor Analysis, is extracted two factors of “characteristics” (eigenvalue=2.538,  $\alpha=0.88$ ) and “development potential” (eigenvalue=1.633,  $\alpha=0.80$ ). The accumulated covariance explained reaches 80.755%.

Environmental behavior, with Factor Analysis, is extracted four factors of “persuasive action” (eigenvalue=3.946,  $\alpha=0.89$ ), “consumption action” (eigenvalue=3.325,  $\alpha=0.90$ ), “ecological management” (eigenvalue=2.862,  $\alpha=0.84$ ), and “legal action” (eigenvalue=2.571,  $\alpha=0.82$ ). The accumulated covariance explained achieves 79.276%.

**Correlation Analysis of environmental attitudes and tourist satisfaction**

To test H1, the analysis result, *Table 1*, shows significant effects of environmental ethics ( $t=2.215^{**}$ ), environmental education ( $t=2.436^{**}$ ), and environmental resources ( $t=2.388^{**}$ ) on characteristics and remarkable effects of environmental ethics ( $t=2.162^{**}$ ), environmental education ( $t=1.934^*$ ), and environmental resources ( $t=2.457^{***}$ ) on development potential that H1 is supported.

**Table 1.** Analysis of factors in environmental attitudes and tourist satisfaction

Dependent variable→	Tourist satisfaction			
Independent variable↓	Characteristics		Development potential	
Environmental attitudes	Beta	t	Beta	t
Environmental ethics	0.211	2.215**	0.203	2.162**
Environmental education	0.233	2.436**	0.188	1.934*

Environmental resources	0.224	2.388**	0.236	2.457***
F	18.324		23.517	
Significance	0.000***		0.000***	
R2	0.168		0.195	
Adjusted R2	0.014		0.017	

Note: \* stands for  $p < 0.05$ , \*\* for  $p < 0.01$ , and \*\*\* for  $p < 0.001$ .

Data source: Self-organized in this study

### ***Correlation Analysis of tourist satisfaction and environmental behavior***

To test H2, the analysis result, *Table 2*, reveals notable effects of characteristics ( $t=2.049^{**}$ ) and development potential ( $t=2.377^{**}$ ) on persuasive action, significant effects of characteristics ( $t=2.261^{**}$ ) and development potential ( $t=1.833^{*}$ ) on consumption action, remarkable effects of characteristics ( $t=2.173^{**}$ ) and development potential ( $t=2.415^{**}$ ) on ecological management, and notable effects of characteristics ( $t=2.227^{**}$ ) and development potential ( $t=2.566^{***}$ ) on legal action that H2 is supported.

***Table 2. Analysis of factors in tourist satisfaction and environmental behavior***

Dependent variable→	Environmental behavior							
	Persuasive action		Consumption action		Ecological management		Legal action	
Independent variable↓	Beta	t	Beta	t	Beta	t	Beta	t
Tourist satisfaction								
Characteristics	0.192	2.049**	0.218	2.261**	0.206	2.173**	0.211	2.227**
Development potential	0.229	2.377**	0.174	1.833*	0.235	2.415**	0.243	2.566***
F	16.416		19.372		22.155		24.882	
Significance	0.000***		0.000***		0.000***		0.000***	
R2	0.173		0.196		0.223		0.241	
Adjusted R2	0.015		0.017		0.020		0.022	

Note: \* stands for  $p < 0.05$ , \*\* for  $p < 0.01$ , and \*\*\* for  $p < 0.001$ .

Data source: Self-organized in this study

### ***Correlation Analysis of environmental attitudes and environmental behavior***

To test H3, the analysis result, *Table 3*, presents significant effects of environmental ethics ( $t=2.233^{**}$ ), environmental education ( $t=2.351^{**}$ ), and environmental resources ( $t=2.138^{**}$ ) on persuasive action, remarkable effects of environmental ethics ( $t=2.259^{**}$ ), environmental education ( $t=2.414^{**}$ ), and environmental resources ( $t=2.323^{**}$ ) on consumption action, notable effects of environmental ethics ( $t=1.942^{*}$ ), environmental education ( $t=2.055^{**}$ ), and environmental resources ( $t=1.826^{*}$ ) on

ecological management, as well as significant effects of environmental ethics ( $t=2.012^{**}$ ), environmental education ( $t=2.436^{**}$ ), and environmental resources ( $t=1.868^*$ ) on legal action that H3 is supported.

**Table 3.** Analysis of factor in environmental attitudes and environmental behavior

Dependent variable→	Environmental behavior							
	Persuasive action		Consumption action		Ecological management		Legal action	
Independent variable↓	Beta	t	Beta	t	Beta	t	Beta	t
Environmental attitudes								
Environmental ethics	0.216	2.233**	0.218	2.259**	0.183	1.942*	0.192	2.012**
Environmental education	0.222	2.351**	0.231	2.414**	0.197	2.055**	0.238	2.436**
Environmental resources	0.207	2.138**	0.227	2.323**	0.176	1.826*	0.171	1.868*
F	17.514		20.628		24.512		26.441	
Significance	0.000***		0.000***		0.000***		0.000***	
R2	0.151		0.168		0.194		0.218	
Adjusted R2	0.013		0.014		0.017		0.019	

Note: \* stands for  $p<0.05$ , \*\* for  $p<0.01$ , and \*\*\* for  $p<0.001$ .

Data source: Self-organized in this study

## Conclusion

The research results show that visitors with positive environmental attitudes towards eco-tourism could better perform correct environmental behavior. Eco-tourism is getting popular in Taiwan, and the promotion by relevant government sectors has various ecological tours be promoted in travel markets in past years. It is therefore a new trend to develop sightseeing. Nonetheless, a large quantity of population flooding in ecological conservation zones would result in pressure on the load of conservation zones. The management of conservation zones in Taiwan is still lack of the concept of visitor capacity and perfect monitoring systems that it could easily result in negative effects on conservation zones. The propaganda and education of environmental conservation and eco-tourism therefore should be reinforced to propagate the importance of ecological conservation and the idea of environment sustainable development to the mass society, reinforce the cognition of environment protection, and timely propagate ecological conservation to the mass society by holding relevant environment protection activity in order to enhance the cognition of ecological environment. In this case, it could avoid or reduce negative impacts on the environment as well as balance the development of sightseeing and ecological conservation to achieve the sustainable management of natural environmental resources.

## Suggestions

Aiming at above research results, the following suggestions are proposed in this study.

1. Relevant governmental sectors are suggested to continuously reinforce the propaganda and education of environmental conservation and eco-tourism when promoting eco-tourism. Wire, wireless TV channels and print media are so advanced nowadays that environmental education, eco-tourism content, and the spirit could be propagated through TV programs or newspaper and magazines.

2. Eco-tourism parks are suggested to continuously present the public authority to have visitors intangibly establish the different image between conservation zones and general recreation areas and to prohibit vendors randomly running in conservation zones to avoid environmental pollution. Ecological conservation zones delivering positive environmental resource conservation information could have visitors learn to respect life, the environment, and culture in the travel process and allow the eco-tourism experience extending to the re-thinking of environment feedback.

3. Relevant sectors are suggested to combine neighboring touring spots, design package tours including ecological and cultural travel, and match with local characteristic produce and food to attract visitors, when promoting eco-tourism. It could further enhance local and economic development.

4. In terms of enhancing the propaganda and education of environmental conservation and eco-tourism, schools and eco-tourism sectors could hold natural environment and ecology related interpretation summer camps to enhance students' cognition of the environment and ecology and to cultivate good environmental attitudes and behavior of the public. In this case, students around eco-tourism parks could be proceeded ecological interpretation activity to train the basic concept about ecological conservation and eco-tourism.

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# THE EFFECTS OF DEEP BALCONY OF DIFFERENT BUILDING HEIGHTS ON INDOOR LIGHTING AND THERMO-ENVIRONMENT

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** The plan for the "Kaohsiung area building" was based on the "different building height depth research on indoor warm sun sets and lighting environmental benefits of Planning" design evaluation. Kaohsiung houses' existing buildings were studied for building information model of "building energy simulation" so as to simulate and evaluate the effectiveness of deep shade type balcony design. The purpose of studying both Houses of different types of buildings in Kaohsiung is to design energy-efficient building exterior balconies with improved planning and design so as to improve simulation predictions and improve measures and deliberations. It is also expected to develop design principles of renovations, including the focus on the consolidation and transformation of energy-saving design details of the housing on the practical application of the analysis with collocation and verified by simulation. The results of the imported ECO-efficiency model (EEM) was used to assess its life-cycle costs and benefits (LCCE) and the research results can provide a different building height depth research on indoor warm sun sets and the environmental benefits of daylighting toward the reference design criteria of sustainable building renovation.

**Keywords:** *deep shade type balcony, fenestration rate, building high-rise, building energy simulation, building Information Model (BIM), ECO-Efficiency model*

## Introduction

According to the statistical data of Kaohsiung Department of Building Affairs: currently, the proportions of "newly built buildings" and "existing buildings" are 7.2% and 92.8% respectively (Department of Building Affairs, Kaohsiung City Government, 2014). Among them, the proportion of "residential buildings" is 60.8%, which is the highest. The Kaohsiung City Kaohsiung Lohas Design Measure stipulates relevant provisions on deep balconies. The design of overhanging eave, sunshade, or balcony etc. can bring cool shelter, highlighting the characteristics of climatic environment in Kaohsiung City. A building which sets deep balcony in response to the local sun light exposure should conform to the following circumstances and at the same time may be exempted from calculating into building area or floor area.

The balcony shall be set outside fifteen degrees of the left and right side to the north of a building respectively. If the exterior central line extruded from the building or the central line of substituted column of the building exceed the three-meter limit, the outer edge thereof shall be deducted three meters respectively from the central line, and based on which the maximum horizontal projected area of floor area will be calculated. The balcony of a building below five floors shall be set at the sides of the site facing road, site interior pathway, private pathway or existing roadway.

A balcony with its width within three meters is excluded from the floor area. The sum of the area of the balcony on each floor shall not exceed one fourth of the floor area. If



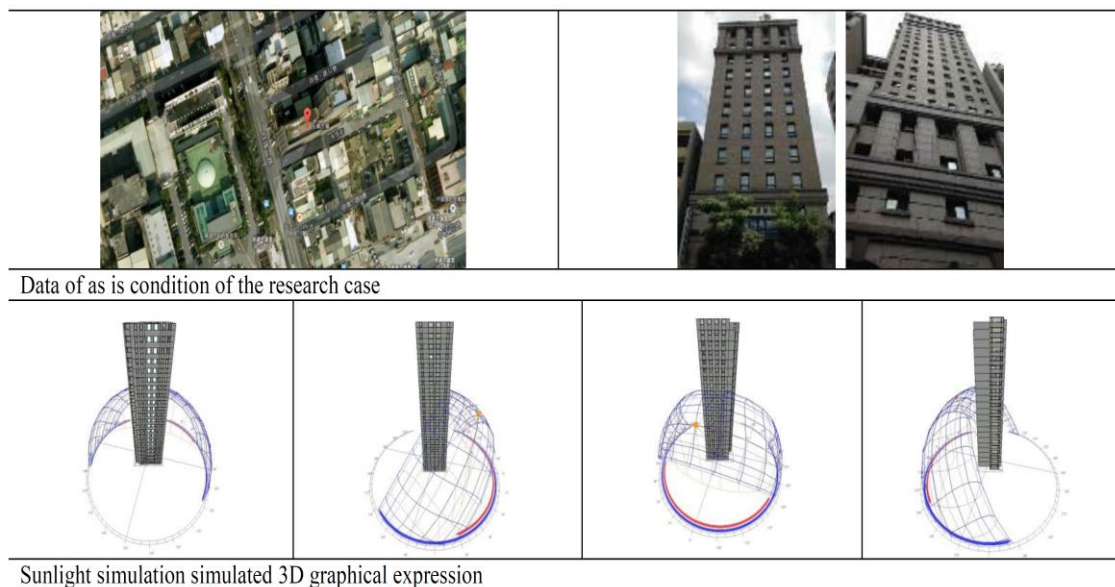
the sum of the area is less than twenty square meters, another balcony of twenty square meters shall be built.

For the vertical plane of balcony on each floor, the opening rate from the legal handrail height to the floorboard of the upper floor shall be above one second of the balcony area and the green area of each balcony shall be more than one third. The depth of soil coverage within the green scope of balcony shall be more than 15 centimeters, and there shall be no column in the balcony.

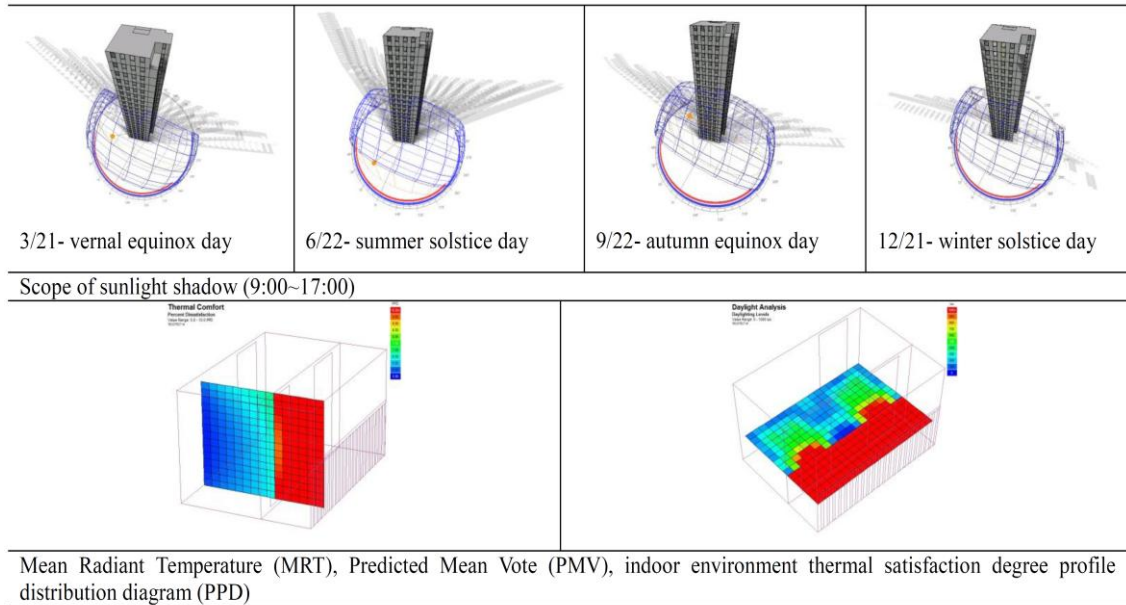
For the living room part of deep balcony set according to this study, the area of each section shall not be less than ten square meters and the depth shall not be less than three meters.

This research carries out reconstruction simulation estimation through the control of different building heights, different depths of deep shade type balconies and different window opening rates (Suh et al., 2014; Yin et al., 2010). Moreover, simulation estimations were conducted based on the "ECO-Efficiency Model" (EEM) (Xu et al., 2014, Volk et al., 2014). The research results serve as the reference for Taiwan sustainable green building reconstruction design criterion and became the reference basis of "Building Envelope Energy Saving Reconstruction Design Technical Specification" in future development of "Kaohsiung Lohas".

This research selected one representative case and used the Autodesk Ecotect software to conduct 3D modeling and simulation. The simulation contents include: deep shade type balcony depth, area size of window opening part, evaluation of energy consumption of sunshine effect, and in consideration of the effect of indoor lighting and thermo-environment caused by different variable factors. The target of the case study is located at No. 22, Ziqiang 1 Road, Qianjin District, Kaohsiung City. The building structure is RC building. The building has twenty-two floors and is about 66 meters high and the floorboard area of each floor is about 255m<sup>2</sup> (Figures 1 and 2).



**Figure 1.** Residential Case Indoor Lighting and Thermo-Environment Simulation Evaluation



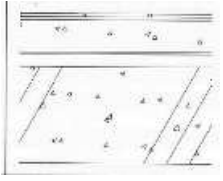
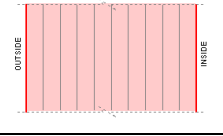
**Figure 2.** Thermo-Environment Simulation Evaluation

## Methodology

This building sets the direction of facing north, according to different floors (7F, 16F, 22F), different shade depths (1.5m, 2m, 2.5m, 3m) and different window opening rates (50%, 75%, 100%). We studied the indoor air conditioner energy consumption, thermo-environment MRT, PPD, PMV (Fanger, 1970; Fanger, 1972; ISO, 2005) and indoor lighting environment etc. (Tsuzuki ind Iwata,2002; Berglund, 1998) and make comparisons across the five simulation results. If taking 1.5 meters as is depth of the balcony as the simulated EUI value as the 100% reference value, when the deep shade of a balcony increases to 2 meters, 2.5 meters and 3 meters, we have compared four shade-type balcony models of different depths and analyzed the energy saving and indoor lighting improvement effects of their air conditioners. The setting values of simulation parameters are as shown in *Table 1*.

**Table 1.** Thermal Conductivity and Property of Residential Case Materials

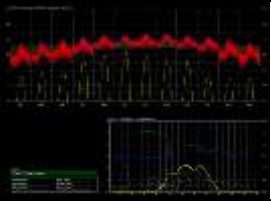
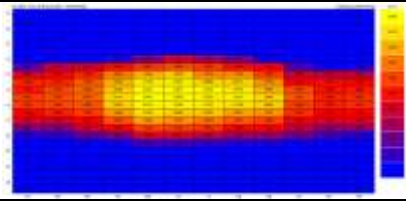
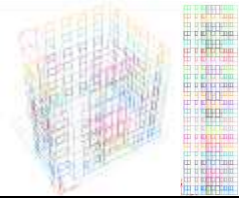
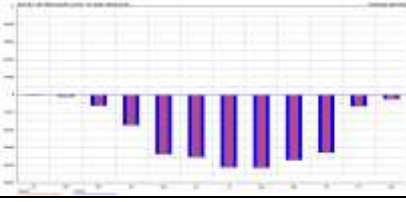
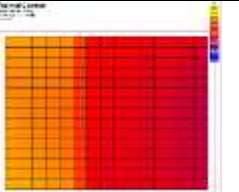
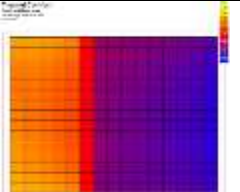
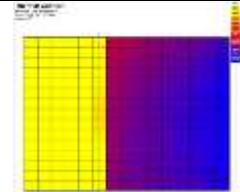
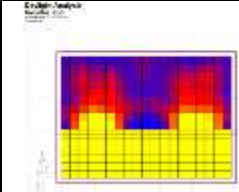
Parameter type Component and material		Thickness (cm)	Density (kg/m <sup>3</sup> )	Specific heat capacity (J/kg·K)	Thermal conductivity coefficient	Thermal conductivity U (w/ E·k)	Structure schematic diagram
Exterior wall	Plaster	1	1250	1088	0.431	2.750	
	Concrete	11	1600	656.9	0.335		
	Plaster	1	1200	1088	0.431		

Roof	Material U value of 1.39						
Window	Clear glass +aluminum window	0.6	2300	836.8	1.046	5.44	
Visible light transmission (%)				0.725			
Solar Heat Gain Coefficient SHGC (%)				0.56			

The steps of simulation flow chart are as follows (*Table 2*):

1. Set the climatic data of Kaohsiung District according to the model site.
2. Review the average time distribution of sunlight radiation per year in Kaohsiung District (the simulation indicates that it is the highest at 16:00 of June).
3. Conduct model construction according to the as is condition of the current case, the current balcony depth of the case sets as 1.5 meters.
4. Conduct all-year air conditioner energy consumption simulation according to the setting of climatic data of Kaohsiung District.
5. Simulate indoor black ball temperature (set the temperature at 23°C~28°C)
6. Simulate PMV (set as 0-1)
7. Simulate PPD (set as 5~90)
8. Simulate indoor daylighting illumination (set at 0~1000Lux)  
 Complete one group of simulation case.

**Table 2.** Flow Chart of Simulation Steps

			
Step 1.	Step 2.		
			
Step 3.	Step 4.		
			
Step 5.	Step 6.	Step 7.	Step 8.

## Results

### *Analysis of air conditioners' energy consumption simulation*

This study established the model according to the actual as is condition of the case, and takes the current balcony depth 1.5 meters as the reference value so as to simulate the air conditioner energy consumption EUI value (see *Table 3*) of different balcony depths (1.5m, 2m, 2.5m and 3m), different floors (7F, 16F, 22F) and different window opening rate of the opening part (as is condition, 50%, 75%, 100%) under the same external condition.

**Table 3. Resultsof Air Conditioner Energy Consumption EUI Simulation**

Balcony depth	1.5M	2M	2.5M	3M
<b>As is condition</b>				
<b>7F</b>	115,985	104,288	93,122	82,264
<b>16F</b>	115,956	97,846	87,341	82,279
<b>22F</b>	124,131	97,983	87,525	87,496
<b>Window opening rate 50%</b>				
<b>7F</b>	116,013	101,943	91,014	82,131
<b>16F</b>	116,032	101,960	91,030	82,145
<b>22F</b>	124,377	108,948	97,146	87,515
<b>Window opening rate 75%</b>				
<b>7F</b>	147,164	129,430	114,415	103,365
<b>16F</b>	147,182	129,447	114,430	103,378
<b>22F</b>	147,902	129,570	114,582	103,530
<b>Window opening rate 100%</b>				
<b>7F</b>	172,440	149,995	132,900	120,078
<b>16F</b>	172,458	150,011	133,095	120,091
<b>22F</b>	173,679	151,016	134,021	120,834

According to different depths under the same climatic condition, the simulated indoor air conditioner energy consumption EUI value obviously indicated that the deeper the shade depth, it can effectively reduce the indoor thermal loading so as to reduce the usage of indoor air conditioner and achieve the effect of CO<sub>2</sub> emission reduction and energy saving.

Analysis of results of 50% window opening rate: it can save approximately 12%~30% of the air conditioners' electricity consumption at most.

Analysis of results of 75% window opening rate: it can save approximately 12%~30% of the air conditioners' electricity consumption at most.

Analysis of results of 100% window opening rate: it can save approximately 13%~31% of the air conditioners' electricity consumption at most.

Under the same balcony depth and window opening rate, the impact of floor height of low and medium floors on the difference of air conditioner energy consumption is not great, except that the air conditioner energy consumption on top floor in high floor case will rise slightly. By comparison, the window opening rate has greater impact on the indoor air conditioner energy consumption than the shade depth.

Under the same floor height and each window opening rate (as is condition, 50%, 75%, and 100%), the depth of deep shade type balcony indeed can affect the air conditioners' energy consumption. Since the increase of the window opening rate will

increase the indoor air conditioner loading, if collocated with deep shade type balcony, it can reduce the impact on indoor air conditioners' energy consumption when increasing the window opening rate.

### ***Thermo-Environment Simulation***

This research also aims at different floors and window opening rates at the same time. We studied the impact of deep shade type balconies on the indoor thermo-environment through simulation comparison and the simulation data include indoor radiation heat, PMV and PPD. The result indicated that: under the condition of same floor, the deeper the balcony depth, the less radiation heat will go indoors. Under the condition of same shade depth, there is no obvious difference in the performance among the low and medium floors, since such simulated high floor is the top floor, the performance effect of deep shade type balconies on high floor is higher than that on low and medium floors.

### ***Indoor Lighting Simulation***

The main impacting variable factors of the indoor lighting environment are the depth of deep shade type balconies and the window opening rates. Moreover, there is no obvious difference among the performance of floor height. The deeper the balcony depth, the less natural light will go indoors and this can reduce the indoor air conditioners' energy consumption relatively. The higher the window opening rate, it can increase the indoor illumination more directly, which increases the indoor air conditioner energy consumption.

### **Discussion**

According to the statistics of GBI, which is mainly based on the frigid climate countries in Europe and America, the energy consumption of a greenhouse system is switched into energy consumption of cool house and thermal insulation. Among them, the proportion of energy consumption of doors and windows are as high as more than 23%. Given this, if the energy consumption in the part of windows can be reduced effectively (Shao et al., 2014), it will contribute to the effect of a certain degree in the control of building energy consumption (Tzeng et al., 2013).

According to the conclusion of the early research (Liu et al., 2014), we can conclude that:

1. The deep shade type balcony can improve the benefit and effect in indoor energy-saving and can reduce almost 12.72% of indoor air conditioners' electricity consumption.
2. The reconstruction of collocated materials of a building envelope and the increasing use of thermal insulation building materials can improve the energy saving benefit, especially then the depth of deep shade type balcony is 3m. After improving the collocated envelope construction materials, up to 40.16% of air conditioner energy consumption can be saved at most.
3. The deeper the depth of the deep shade type balcony, the better the energy saving effect will be; the higher the deep shade floor, the better the energy saving effect will be.

## Conclusion

1. For a window opening rate of 50%, it is suggested to adopt 2.5m deep shade type balcony. When sacrificing partial natural lighting, it can save about 21-22% of the electricity consumption.
2. For a window opening rate of 75%, it is suggested to adopt 3m deep shade type balcony. Without impacting the indoor natural lighting, it can save about 29-30% of the electricity consumption.
3. For a window opening rate of 100%, it is suggested to adopt 3m deep shade type balcony. Without impacting the indoor natural lighting, it can save about 31% of the electricity consumption.

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# THE ENERGY SAVING STRATEGY ON THE SUSTAINABLE CAMPUS RENOVATION PLAN BY RECYCLING AND REUSE OF RAINWATER IN TAIWAN

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** The main purpose of this study is to investigate the energy saving strategy on the Sustainable Campus Renovation Plan by recycling and reuse of rainwater in Taiwan. Case studies from the past were also investigated for effectiveness comparisons, which include both economical values and environmental values. Data Envelopment Analysis (DEA) has been implemented for quantification purposes and it provided the visualization and comparison of energy saving improvement database. Moreover, a model for assessing the improvement on the recycling and reuse of rain water could be constructed. In addition, a set of improved strategy process and steps of rain water recycling and reuse methodology may be proposed which result in the vision of the Sustainable Campus Renovation establishment.

**Keywords:** *sustainable school, rainwater recycle, rainwater reuse, energy, Data Envelopment Analysis (DEA)*

## Introduction

In Chapter 36 of Agenda 21, compiled in Rio 1992, a reference is made to: “Education, raising of public awareness and training are linked to virtually all areas in Agenda 21, and even more closely to the ones on meeting basic needs, capacity-building, data and information, science and the role of major groups. Education, including formal education and training, should be recognized as a process by which human beings and societies can reach their fullest potential”.

The Sustainable Campus Renovation Plan by the Ministry of Education, Taiwan has been carried out for 13 years based on two major topics which include the “environmental suitability” and the “sustainable education”. School teachers and students proactively identified campus environments which are unfriendly, ineffective in energy saving, and not sustainable. Therefore, proposals on the improved countermeasures have occurred via brainstorming. In addition, these have been implemented to the participant-centered learning program during the beginning, mid-term, and final stage of reengineering process and have integrated the improved result into the academic circle to enable school students to personally feel the wonderfulness of environmental re-establishment and truly identify the importance of sustainability. Thus, schoolyards needs an appropriate assessment tool to examine the intrinsic and extrinsic effects with regard to the Environmental Protection and Ecology (Liao et al., 2014).

It is known from the average annual rainfall that the water resource is unevenly distributed in Taiwan. Therefore, drought occurs easily and the Ministry of Education has proactively promoted the concept of correctly using the water resources, and request school to assess water facilities progressively and to improve budget planning on a

yearly basis. Furthermore, in order to save valuable water resources, the Sustainable Campus Renovation Plan by the Ministry of Education provides subsidies to improve the facilities on rainwater recycle system, turning the output of the system into restroom flush or plants watering. Growing water scarcity and global climate change both call for more efficient alternatives of water conservation. The rainwater harvesting (RWH) is the most promising alternative among others. (Magliano et al., 2015). This study fully utilizes the result from a past case study of campus sustainability as the database and consolidates the energy-saving technology (rainwater recycling and reuse) which the Sustainable Campus Renovation Plan proposed by the Ministry of Education, Taiwan in an attempt to promote the investigation of the pros and cons of the energy-saving efficiency. Therefore, the results lead to the construction of energy-saving efficiency assessment model and the establishment of improved energy-saving strategies. This assessment model and strategy shall therefore be considered as one of the most significant factors in the future renovation of the school.

## **Materials and methods**

This study has collected data from campuses which have rainwater recycle improvement case and impose the view of environmental efficiency. The key factors include improving the energy saving (input) / assessment factor as the output. With this opportunity, it is expected to better understand the technique of localized energy-saving improvement. In order to provide relevant scientific facts and a quantitative analysis and to provide the most suitable energy-saving strategy for school building in Taiwan, this study used the Data Envelopment Analysis (DEA) of Multiple-Criteria Decision Analysis (MCDA) as the main analytical method. In addition, the result shall prevent campus management and designer from selecting poor energy-saving techniques and to avoid the waste of resources and money.

### ***Selection of analytical modes***

Recently, some studies have applied DEA to macro performance assessment, energy control solutions and cost-benefit empirical models in order to improve overall efficiencies (Macek and Marik, 2012; Chang and Yang, 2011). DEA has recently become a popular approach for measuring the energy and environmental performance at the macro-economy level (Wang et al., 2013; Yu and Chan, 2012; Blomberg et al., 2012).

Traditional CCR model and BCC model are the measure of radial efficiency. These two models hypothesize that input and output could be increased or decreased proportionally. During the calculation process, a decision has to be made whether it is input or output orientated, and could not take both into consideration at the same time. Tone (2001) proposed the SBM (Slack-Based Measure) model in which variance variables are taken into consideration as the measurement fundamental. The assessment model of SBM is based on non-radial, and it takes into consideration the variance for both the input and the output. This amends not only the shortage of CCR model and BCC model (measure of radial efficiency) but also the drawback of unit invariance. Song et al. (2013) raised the new model's computing conclusions are highly related to the efficiency assessment of the DEA-SBM model. Moreover, his study emphasized more on the affects of undesirable outputs on production efficiency than the latter. This



means the new model has a greater extensive value for application and provides a better quantitative theoretical basis for environmental policy analysis.

In accordance with the derivation by Tone (2001), the efficiency value derived from SBM model will not exceed the efficiency value derived from the CCR model. As for units which have been assessed, the SBM efficiency value ( $\rho=1$ ) is equivalent to the CCR model's efficiency value. Therefore, the SBM model has been selected as the analytical model for the efficiency measurement. The fractional linear programming of the SBM efficiency value is illustrated by Eq. 1 as follows:

$$\min \quad \rho = \frac{1 - \frac{1}{m} \sum_{i=1}^m s_i^- / x_{io}}{1 + \frac{1}{s} \sum_{r=1}^s s_r^+ / y_{ro}} \quad (\text{Eq.1})$$

$$\text{s.t.} \quad x_o = X\lambda + s^-$$

$$y_o = Y\lambda - s^+$$

$$\lambda, s^-, s^+ \geq 0$$

In Eq. 1,  $\rho$  is variance index of non-radial,  $s_i^-$  and  $s_i^+$  represent variance and output variance,  $X\lambda$  &  $Y\lambda$  represent the benchmark of efficient frontier for both input and output. If we assume  $X \geq 0$  and if  $x_{io}=0$  then  $s_i^-/x_{io}$  has to be removed from the objective function. In order for  $s_i^+/y_{ro}$  to highlight the negative impact on the SBM efficiency,  $y_{ro}$  has to be replaced by minimum positive value when  $y_{ro} \leq 0$ .  $0 \leq \rho \leq 1$  represent SBM efficiency value is being limited between 0~1. Since  $\rho$  uses the index constructed by both  $s_i^-$  and  $s_i^+$ , when all of the values of  $s_i^-$  and  $s_i^+$  are 0 it indicates that all the input and output values of DMU present no variance. Therefore, when  $\rho=1$  we can conclude that DMU has SBM efficiency.

### ***The interpretation of the result***

Since DEA models are vulnerable to the attributes of inputs and outputs and the data of DMUs, this study employs both the efficiency and the susceptibility analyses to identify the changes and causes of respective decision-making units besides the SBM for improved validity.

Efficiency analysis: According to Chang et al. (1995) the efficiency refers to the level with which an objective is achieved. We compute the efficiency scores of respective DMUs by substituting 1 as the input of DEA.

Susceptibility analysis: We identified how the changes of inputs and outputs affect the relative efficiency scores of respective DMUs and ascertain the affected levels of respective outputs on a DMU by excluding the SBM result of a specific output and observing how the efficiency scores change accordingly. *Table 1* illustrates the method of sensitivity analysis.

**Table 1. Data analysis**

	Efficiency Analysis	Effectiveness Analysis	Sensitivity Analysis				
			Input 1 removed	Input 2 removed	Output 1 removed	Output 2 removed	Output 3 removed
			-I1	-I2	-O1	-O2	-O3
Input 1	⊙	-	-	⊙	⊙	⊙	⊙
Input 2	⊙	-	⊙	-	⊙	⊙	⊙
Output 1	⊙	⊙	⊙	⊙	-	⊙	⊙
Output 2	⊙	⊙	⊙	⊙	⊙	-	⊙
Output 3	⊙	⊙	⊙	⊙	⊙	⊙	-

Remark: ⊙ Impose SBM model into the calculation of input and output.

## Results and discussion

### *Investigations on the energy-saving efficiency of rainwater recycling and reuse system by using DEA*

Rainwater recycling and reuse subsidy program under the Sustainable Campus Renovation Plan by the Ministry of Education, Taiwan has experienced several stages of turning points. During the early stage of the subsidy, schools have proactively recycled and centralized water source collection in an attempt to cope with improvements on rainwater reusability plan. However, these water sources consist of rainwater, water for washing hands, water for cleaning vegetables, RO water, spring water etc. since water came from different sources with different pollution/contamination levels. Therefore, using a simple filtration system does not guarantee an effective management of those recycled water. In addition, this could result in water pollution/contamination and could lead to issues which may cause school extra efforts in maintenance management. Rainwater is only one of the sources of recycle water. There are other water sources and these are mainly from used tap water or groundwater. If these were to be recycled, pollution/contamination risk shall be taken into consideration

In view of this, from its early stage. the reformation of recycling water under sustainable campus program needs to have dynamic transformation techniques on ecological pool, kitchen water and grease separation, rainwater recycling and reuse. However, due to the consideration of “water quality management”, the program has recently been constrained to the recycling and reuse of rainwater only. Although the source of rainwater is not as complex as other sources, the transformation technique which is derived from rainwater treatment is not anything less. In the early phrase, a single water tank was used for water collection purpose, then changed to “gravity water supply”. The purpose of this approach is to have a recycling water tower located on top floor, and to better utilize the school buildings’ raft foundation for water collection purpose. Moreover, underground excavations in school area were carried out to set up water collection tank. Therefore, high ground water tank, underground RC water tank, and raft foundation water tank are the major three significant factors which this study investigate upon on the efficiency of rainwater recycling and reuse. The water quality of

an ecological pool is difficult to maintain and manage. Moreover, due to safety issues and the instability of water sources during different seasons, the campus sustainable program currently does not encourage this to be included in the program and thus they have been excluded throughout this study.

With reference to this topic, the purpose of this study is to investigate and compare the efficiency of recycling and reuse on “High ground water tank (recycling & reuse)”, “underground RC water tank collection”, “high ground water tank with rafted foundation”. Based on the above clarification, this study will set “early phrase establishment cost (dollar)”, and “estimated maintenance management cost (dollar/year)” as the input, and “area of rainwater collection (m<sup>2</sup>)”, “water storage capacity (ton)”, and “re-utilization (ton)” as the output (*Table 2*). SBM-O-C model has been selected to calculate the improved efficiency value. The definition of output will be used in accordance to Clause 2, Article 309 under the Construction Design of Building Technical Regulations. The collection and calculation conversion of input and output are clarified as follows:

(I1) Early phrase establishment cost (dollar): actual cost of engineering contracts for that particular year. It is calculated in dollars.

(I2) Estimated maintenance management cost (dollar/year): Schools were asked to estimate the budget required for day-to-day maintenance and management. It is calculated in dollars.

(O1) Area of rain water collection (m<sup>2</sup>): The area of rain water collection from the use of facilities and buildings, for instead, the projected roof or canopy.

(O2) Water storage capacity (ton): The amount of rain water stored from the use of water storage tank and building. This excluded the facility which runs water quality treatment process.

(O3) Re-utilization (ton): The amount of rain water stored from the use of facilities and effective rainwater utilization. This is calculated in tons and rounded up to one digit after the decimal point. In order to cope with the data of the Sustainable Campus Renovation Plan by the Ministry of Education provided by each school, the re-utilization statistical data will be based on May-Aug of the coming year upon on the completion of the improvement.

**Table 2.** Rainwater (Recycling & Reuse)- Original Data

DMU Code	Recycling Method	Motor Usage	Filtrations Facility	Re-utilization method	Original Data				
					(I1)	(I2)	(O1)	(O2)	(O3)
					Early phrase establishment cost (dollar)	Estimated maintenance management cost (dollar/year)	Area of rain water collection (m <sup>2</sup> )	Water storage capacity (ton)	Re-utilization (ton)
1	PVC bucket	NO	Filter	Watering	27560	150	50	1.12	61
2	Stainless Water Tower	YES	Rainwater Sedimentation Tank	Flushing toilet, Watering, floor cleaning	723600	1500	900	22	1720
3	Stainless Water Tower	NO	Filter	Watering, rehydrate	52000	200	209	3	90

DMU Code	Recycling Method	Motor Usage	Filtrations Facility	Re-utilization method	Original Data				
					(I1)	(I2)	(O1)	(O2)	(O3)
					Early phase establishment cost (dollar)	Estimated maintenance management cost (dollar/year)	Area of rain water collection (m <sup>2</sup> )	Water storage capacity (ton)	Re-utilization (ton)
				wetland					
4	Stainless Water Tower	NO	Filter Basic Filter Tank	Watering	115000	300	946	10	300
5	Stainless Water Tower	NO	NO	Watering, rehydrate wetland	98000	300	720	10	245
6	Stainless Water Tower	NO	NO	Watering	564000	1500	652	15	604
7	Stainless Water Tower	YES	NO	Watering, rehydrate wetland	60000	200	200	5	160
8	Stainless Water Tower	YES	Filter	Watering, rehydrate wetland	380000	1000	306	6	312
9	Stainless Water Tower	NO	NO	Watering	278500	750	1170	15	350
10	Stainless Water Tower	NO	Basic Filter Tank Filter	Watering	319200	800	1265	20	210
11	Stainless Water Tower	NO	NO	Watering	665000	200	640	10	65
12	Stainless Water Tower	YES	NO	Watering	435886	1200	567	15	360
13	Stainless Water Tower	YES	Sedimentation pool	Watering	205000	500	782	10	165
14	Stainless Water Tower	YES	NO	Watering	835045	200	60	3	56
15	Stainless Water Tower	NO	NO	Watering	66000	200	360	10	43
16	Stainless Water Tower	NO	NO	Flushing toilet, Watering	260000	600	2100	15	310
17	Stainless Water Tower	NO	NO	Watering	40000	100	160	5	42

DMU Code	Recycling Method	Motor Usage	Filtrations Facility	Re-utilization method	Original Data				
					(I1)	(I2)	(O1)	(O2)	(O3)
					Early phase establishment cost (dollar)	Estimated maintenance management cost (dollar/year)	Area of rain water collection (m <sup>2</sup> )	Water storage capacity (ton)	Re-utilization (ton)
18	underground RC water tank collection	YES	10M Ecological river	Watering, rehydrate wetland	580000	1500	507	68	528
19	underground RC water tank collection+ water tower	YES	Sedimentation pool	Watering	216000	600	882	10	220
20	underground RC water tank collection	YES	NO	Watering	281760	700	781	15	322
21	underground RC water tank collection+ water tower	YES	Filtration tank	Flushing toilet, Watering	186074	500	500	31	204
22	Rafted foundation + water tower	YES	Sedimentation pool	Watering	230000	600	542	300	460
23	Rafted foundation	YES	Filter	Flushing toilet, Watering, fire hydrant	160000	500	1206	306	1118

Table 3 refers more detail in the rainwater recycle improvement efficiency rate for “High ground water tank (recycling and reuse)”, “underground RC water tank collection”, “high ground water tank with rafted foundation”.

**Table 3.** Rainwater (Recycling & Reuse)- Efficiency Analysis, Effectiveness Analysis and Sensitivity Analysis

DMU Code	Recycling Method	Case Group	Efficiency Analysis	Effectiveness Analysis	Sensitivity Analysis				
					-I1	-I2	-O1	-O2	-O3
					Early phase establishment cost	Estim ated maintenance	Area of rain water collection removed	Water storage capacity removed	Re-utilization removed
1	PVC bucket	High Ground water tower (Recycling & Reuse)	0.055	0.010	0.032	0.055	0.040	0.274	0.039
2	Stainless Water Tower		0.063	1.000	0.063	0.042	0.046	0.324	0.044
3	Stainless Water Tower		0.077	0.025	0.062	0.077	0.054	0.338	0.057
4	Stainless Water Tower		1.000	0.084	0.356	1.000	0.097	1.000	1.000
5	Stainless Water Tower		0.136	0.081	0.136	0.133	0.095	0.534	0.103
6	Stainless Water Tower		0.041	0.124	0.041	0.035	0.030	0.180	0.030
7	Stainless Water Tower		0.108	0.040	0.101	0.108	0.078	0.410	0.079
8	Stainless Water Tower		0.026	0.051	0.026	0.022	0.018	0.133	0.018
9	Stainless Water Tower		0.081	0.122	0.081	0.070	0.057	0.316	0.062
10	Stainless Water Tower		0.087	0.147	0.087	0.070	0.061	0.199	0.077
11	Stainless Water Tower		0.385	0.060	0.385	0.015	0.105	0.494	0.422
12	Stainless Water Tower		0.049	0.117	0.049	0.043	0.035	0.159	0.037
13	Stainless Water Tower		0.077	0.077	0.077	0.060	0.054	0.240	0.062
14	Stainless Water Tower		0.053	0.021	0.053	0.004	0.041	0.125	0.041
15	Stainless Water Tower		0.125	0.050	0.125	0.121	0.088	0.170	0.147
16	Stainless Water Tower		1.000	1.000	1.000	0.243	0.069	1.000	1.000

17	Stainless Water Tower		0.157	0.031	0.157	0.126	0.114	0.293	0.145
18	Underground RC water tank collection	Underground RC water tank	0.111	0.333	0.111	0.092	0.101	0.148	0.097
19	Underground RC water tank collection + water tower		0.067	0.081	0.067	0.060	0.047	0.258	0.052
20	Underground RC water tank collection		0.084	0.118	0.084	0.067	0.060	0.285	0.065
21	Underground RC water tank collection + water tower		0.169	0.169	0.169	0.145	0.130	0.253	0.163
22	Rafted foundation + water tower	Rafted foundation + water tower	0.440	0.529	0.440	0.368	0.483	0.358	0.513
23	Rafted foundation + water tower		1.000	1.000	1.000	1.000	1.000	1.000	1.000

This study categorized projects into sub-groups and has obtained the average rate of efficiency analysis, effectiveness analysis and sensitivity analysis (*Table 4* and *Fig. 1*):

1.- “Efficiency analysis” on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.720), underground RC water tank collection (0.207), high ground water tank with rafted foundation (0.108)

2.- “Effectiveness analysis” on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.765), underground RC water tank collection (0.179), high ground water tank with rafted foundation (0.175)

3.- “Sensitivity Analysis” (-I1) on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.720), underground RC water tank collection (0.167), high ground water tank with rafted foundation (0.108)

4.- “Sensitivity Analysis” (-I2) on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.684), underground RC water tank collection (0.131), high ground water tank with rafted foundation (0.091)

5.- “Sensitivity Analysis” (-O1) on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.742), underground RC water tank collection (0.085), high ground water tank with rafted foundation (0.064)

6.- “Sensitivity Analysis” (-O2) on average: The rainwater recycle improvement efficiency rates are as follows:

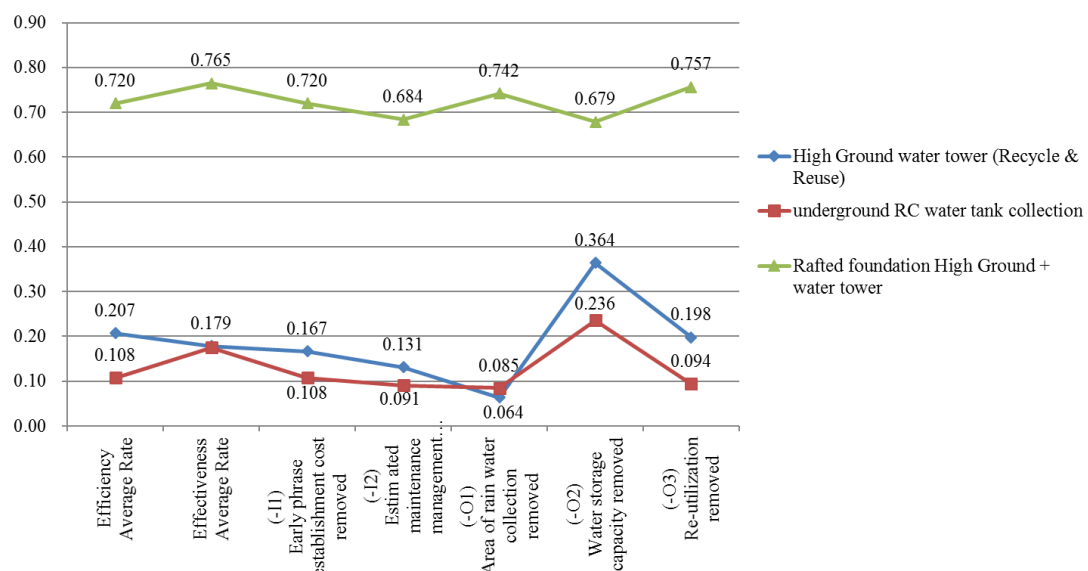
High ground water tank (recycling & reuse) (0.679), underground RC water tank collection (0.364), high ground water tank with rafted foundation (0.236)

7.- “Sensitivity Analysis” (-O3) on average: The rainwater recycle improvement efficiency rates are as follows:

High ground water tank (recycling & reuse) (0.757), underground RC water tank collection (0.198), high ground water tank with rafted foundation (0.094)

**Table 4.** Rainwater (Recycling & reuse)-Case Group by using SBM Model Analysis score value

Code	Case Group	(Combine) DMU Code	Efficiency Average Rate	Effectiveness Average Rate	Sensitivity Analysis Average Rate				
					-I1	-I2	-O1	-O2	-O3
					Early phrase establishment cost removed	Estimated maintenance management cost removed	Area of rain water collection removed	Water storage capacity removed	Re-utilization removed
1.	High Ground water tower (Recycling & reuse)	1-17	0.207	0.179	0.167	0.131	0.064	0.364	0.198
2.	underground RC water tank collection	18-21	0.108	0.175	0.108	0.091	0.085	0.236	0.094
3.	Rafted foundation High Ground + water tower	22-23	0.720	0.765	0.720	0.684	0.742	0.679	0.757



**Figure 1.** Rainwater (Recycling & reuse)- Susceptibility analysis



Overall: Based on the efficiency analysis, the re-utilization of high ground water tank with rafted foundation performs better than High ground water tank (recycling & reuse) and underground RC water tank collection. The main advantage is on the storage capacity. There is a minor difference with regard to the re-utilization of High ground water tank (recycling & reuse) and underground RC water tank collection (Fig. 2).

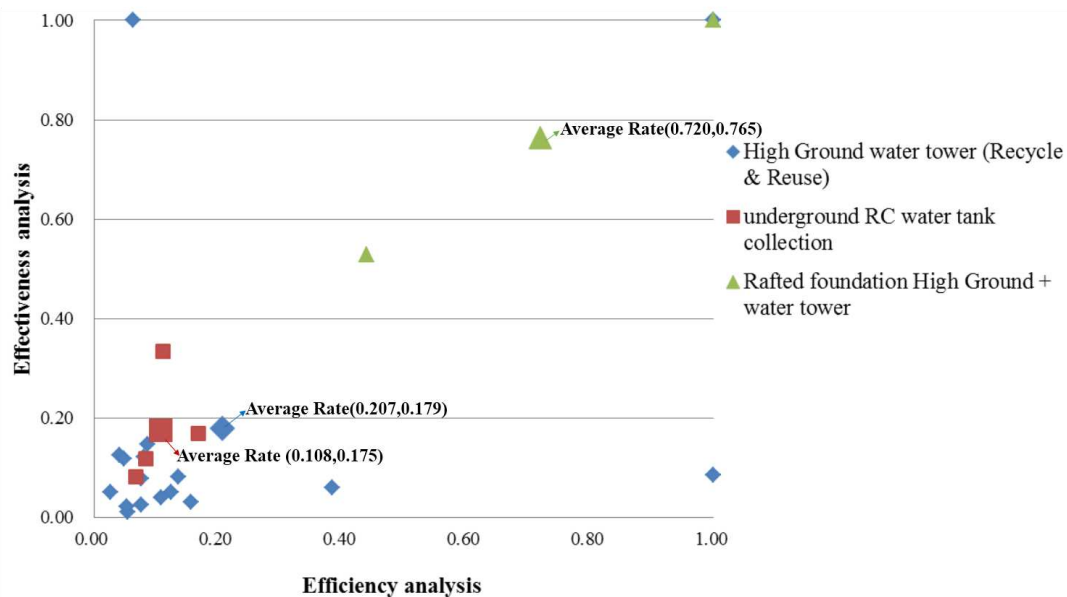


Figure 2. Effectiveness Analysis and Efficiency Analysis scores

## Conclusion

This study conducted a case study of schools which have implemented energy-saving plans, and proposed the improvement checklist which would be suitable for energy-saving program for schools in Taiwan. Throughout this study, the “environmental efficiency” concept and the “Data Envelopment Analysis (DEA)” analysis have been implemented. In addition, input/output factors are taken into consideration. Moreover, efficiency analysis, effectiveness analysis, and sensitivity analysis are used to better understand the techniques of localized “energy-saving” method. With the above, analytical models for “water-saving”, “healthy-saving” and “energy control” could be established and constructed.

The case study and the analysis have provided an empirical evidence that high ground water tower with rafted foundation shows best efficiency performance (Fig. 2). In practice, the method of high ground water tower with rafted foundation has the advantage of large water storage capacity. However, the disadvantage is the re-utilization water source came from underground, and requires extra power to pump the water from bottom to the top. In addition, the gravitational method of supplying water is required. Moreover, in terms of environmental education, the educational observation of rain collection is not easy. Creative observation holes and float balls are required. High ground water tower with rafted foundation is able to collect a large volume of rainwater and therefore the re-utilization of rainwater shall be more diversified. The case study indicated that a flushing toilet takes a large part of water consumption and it shall reuse

rainwater instead of running water. If allowed by the conditions, watering plants and floor cleaning shall also use rainwater. In addition, approaches such as the close monitoring of water consumption and promoting energy-saving can maximize the effectiveness of rainwater recycling and reuse strategy.

**Acknowledgements.** Support for this study is gratefully acknowledged from the cases of the Sustainable Campus Renovation Plan by the Ministry of Education, Taiwan. We also thank two anonymous reviewers for their valuable comments and suggestions.

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# A STUDY ON THE ECOTOURISM COGNITION AND ITS FACTORS

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** Due to the practice of two-day weekend, the public gradually emphasize the demand for tourism, and ecotourism becomes the best leisure and entertainment activity. Taking the development of ecotourism as the center of tourism and recreation, ecotourism activity would cause certain degree of impact on the environment, when paying attention to the quality of leisure life. In this case, changes in ecology would appear negative impact on the environment. Aiming at Tianmen Mountain Ecological Tourism Scenic Spot, the visitors, as the research subjects in this study, are distributed 300 copies of questionnaire. A total of 224 valid copies are retrieved, with the retrieval rate 75%. The research results are summarized as following. 1. Ecotourism cognition presents significantly positive effects on environmental attitudes. 2. Environmental attitudes show remarkably positive effects on environmental impact. 3. Ecotourism cognition reveals notably positive effects on environmental impact. Suggestions, based on the results, are proposed in this study, expecting to develop ecotourism as well as reduce the impact on the environment.

**Keywords:** *environmental awareness, environmental impact, environmental attitudes, citizen participation, social*

## Introduction

The advance of high technology has constantly enhanced the quality of human life, and the public gradually emphasize the demand for tourism. Nevertheless, in face of the continuous occurrence of major natural disasters in recent years, the utilization of natural resources therefore should stress on safety. In addition to the development of technology industry and the promotion of national income, leisure, tourism, and travel have become a part of human life. Ecotourism, with the function of ecological education, focuses on deep experience in the unique nature and culture as well as the natural ecology. When the quality of leisure life is emphasized, ecotourism activity would still impact the environment to some degree to change the ecology and even appear negative impact on the environment.

The practice of two-day weekend has ecotourism become the best leisure and entertainment activity for the citizens. Taking ecotourism as the core of tourism and recreation, the impact on the environment would be relatively enhanced. By understanding the environmental impact caused by tourism activity and reducing the impact with management strategies, the environmental impact resulted from ecotourism activity would be more positive. The past recreation activity concentrated on developed scenic recreation areas with lower local environmental sensitivity than natural areas. Nonetheless, the higher use frequency, the management attitudes, site development, and visitor behaviors could result in the stress on the environment. The recreation environment therefore reveals over carrying capacity. Ecotourism, integrating

environmental awareness into recreation behaviors, could achieve the purpose of instruction through entertainment. It is a key development direction for domestic and international environment conservation and tourism development. As a matter of fact, the key lies in the public sense of mission to protect the environment. Visitors have to deeply understand the value of environmental heritage and the responsibility for the environment. People have no right to advance the tourism and recreation treasure. Tourism activity could really be sustainably developed merely by insisting on the definition and principles of ecotourism; especially, tourism policies have been emphasized in advanced and developed countries.

## **Literature review and hypothesis**

### ***Ecotourism cognition***

Mair (2011) regarded ecotourism, based on natural resources, as the historical and geographic heritage of human beings, the environmental protection and environmental education, and the regional profits achieving the objective goal and the sustainable development. Coghlan (2012) considered ecotourism as nature and culture oriented tourism. Lee (2011) pointed out ecotourism as a travel pattern initially based on local natural history and inherent culture. Ecotourists, when visiting an undeveloped area based on the spirits of appreciation, participation, and perception, would not appear expendable damage on wild creatures and natural resources in the tourism process, but contribute to the living economy of local citizens through employment or other economic tactics. Local governments regard ecotourism as a management method to acquire funds for establishing or developing the area and communities through business management. The cognitive component contains direct experience or information acquired from various channels to form knowledge and perception for the subject matter of attitudes. Such knowledge and the generated perception form the so-called beliefs, representing that consumers believe in certain attributes and characteristics of such subject matter and special results generated by different behaviors (McKercher et al., 2010). Neuhofer et al. (2012) defined cognition as the psychological process to know and comprehend affairs. The result of the cognition process is belief, which is defined as the cognition evaluation of affairs according to specific attributes or characteristics. Cognition is the temporary understanding, knowing, and opinions of a person to people or affairs (Phillips et al., 2013). Lu and Stepchenkova (2012) defined “cognition”, with general explanations, as all forms of knowing, including feeling, memory, inference, perception, plan, notice, imagination, expectation, decision, problem-solving, and thought communication to further discuss the ecotourism cognition of visitors. Regarding the promotion of tribal ecotourism by Maori in New Zealand, Puhakka (2011) indicated that allowing the cognition and participation of citizens could have them show the participation intention in ecotourism, including “economic dimension”, “psychological dimension”, “social dimension”, and “political dimension”. Referring to Han et al. (2011), “environmental awareness”, “citizen participation”, “economic feedback”, and “public funds” deducted from the factor analysis of citizens’ ecotourism cognition and attitudes are used as the ecotourism cognition dimensions in this study.

### ***Environmental attitudes***

Generally speaking, attitudes are the result of cognition and learning process, responding to the feeling or opinions to like or dislike certain affairs (Eijgelaar and de Kinderen, 2014). Attitudes also refer to an individual, towards people, affairs, objects, and surrounding world, presenting a lasting and consistent behavior intention depending on the cognition and preference (Kang et al., 2012). Currently, the commonest definition of attitudes combines the elements of cognitive theory and learning theory. That is, the attitudes towards any affairs, concepts, or people are a lasting orientation towards such people, affairs, objects, or concepts based on cognition, affection, and behaviors (Andrades-Caldito et al., 2013). The environmental attitudes in this study are referred to Huang (2012) that humans form the attitudes towards specific people, affairs, and objects through cognition, affection, and behaviors. Such components of attitudes are explained as below (Gössling, 2011):

#### (1) Cognitive component

It refers to individual cognition of the attitude object, including the fact, knowledge, and belief of such an object. It is the belief, evaluation, or opinions about people or affairs. "Cognition" is personal understanding, knowing, and opinions about an "attitude object" (Heimlich and Ardoin, 2012). Cognition covers broad meanings, including the complicated psychological activity of perception, imagination, identification, reasoning, and judgment (Mobley et al., 2010).

#### (2) Affective component

It contains individual evaluation of the feeling, emotion, or concern about the object. In other words, affective component is a part of emotion or affection, which would generate with concepts, including feeling and emotion, i.e. the preference and disgust at the attitude object (Shrode, 2012). It could be individual positive and negative emotion judgment of certain objects doing good or bad (Lawrence, 2012).

#### (3) Behavior component

It refers to individual reaction or behavior intention to the object, i.e. the preparation of behaviors. It is the potential power and preparation state of agreeing or disagreeing with certain objects, people, or situations (Trochidis and Bigand, 2015). It could also be the inner process of an individual consciously, purposively, and in a planned way approaching the pursued goal (Robeia et al., 2011).

### ***Environmental impact***

De Ávila (2011) defined impact as the change and effect, or new conditions resulted from certain activity or a series of relevant events, which existed in double-edged, i.e. positive profit impact and negative impact. Tourism activity would result in impact on local economy, social culture, and environments. The effect of tourism on economy has been broadly studied. Early research stressed more on positive economic benefits, but ignored the impact of tourism on local economy. Tourism is rapidly developed in the world as people agree with the advantage of tourism for economic prosperity (Fielding and Head, 2012). The boom of tourism industry reveals that more and more countries and regions would be impacted by the growth of tourism. It is broadly agreed that recreational areas present distinct capacity of tourists in accordance with time and location. When the number of tourists is restricted under the extreme level and the

economic influence is positive, the appearance of tourists would be accepted and welcomed by most citizens. Once the number is over the limit, a lot of negative effects would result in the citizens' dissatisfaction to appear xenophobic thoughts and behaviors (Nishiyama and Terasawa, 2013). Regardless of the positive or negative impact of tourism, Young, Pizam, Ryan, Mathieson, and Wall classified tourism impact into economic impact, social and cultural impact, and physical environment impact (Kim et al., 2011).

Referring to Choi and Ritchie (2014), three levels of the ecotourism impact on the environment are applied to this study.

- (1) Environment level: When visitors are not controlled and limited, they would no doubt destroy the environment. The prevalence period of ecotourism is normally the important season for animals and plants maintaining the species survival. Visitors are lack of information about the carrying capacity of the destinations that ecotourism exists damage in the environment.
- (2) Economic level: Most ecotourists come from the northern hemisphere with travel agents handling the tours that local medium and small enterprises could not develop, economic profits return to advanced countries, and local citizens cannot make profits.
- (3) Social and cultural level: Local citizens could merely receive few profits from visitors, and even are regarded as a tourism product. Visitors cause impact on local culture, and the youth learn foreign culture but ignore to pass down traditional culture.

### ***Research hypothesis***

Lawrence (2012) found out the positive correlation between citizen supports with tourism and perceived positive effects as well as the negative correlation with perceived negative effects. Trochidis and Bigand (2015) regarded environmental attitudes as individual supports with environmental affairs. Wang (2010) discovered that local citizens would tend to increase tourism limitations and tax when they perceived negative tourism impact. Neuhofer et al. (2012) indicated that observable and judgable attitudes could be formed merely when cognition, affection, and behavioral intention were taken into account. "Cognition" was related to knowing and understanding the relationship between expression situations and attitude objects, which belonged to thoughts or reason. "Affection" was related to emotions accompanied with ideas or topics, including individual emotional judgment of people, affairs, and objects. "Behavioral intention" was related to the pre-arrangement or preparation of behaviors, containing individual reaction or reaction to people, affairs, and objects. Accordingly, the following hypothesis is proposed in this study.

H1: Ecotourism cognition presents significantly positive effects on environmental attitudes.

Coghlan (2012) regarded environmental attitudes as the lasting and consistent psychological state of an individual about the problems related to the environment, i.e. individual environmental attitudes. Environmental attitudes therefore were the lasting psychology state of an individual about environmental cognition and the preference. Nishiyama and Terasawa (2013) pointed out environmental attitudes as the gather of beliefs which would affect individual activity related to environmental issues or keep

the behavioral intention. In other words, environmental attitudes were the important reference to consumer concerns for psychological health and environment. De Ávila (2011) studied human actions on protecting or preserving the environment. Puhakka (2011) indicated that attitudes could be the predictive variable of behavioral intention, when selecting tourism, to explain the diversity of personal behaviors. The following hypothesis is therefore proposed in this study.

H2: Environmental attitudes show remarkably positive effects on environmental impact.

Huang (2012) considered that ecotourism appeared the minimum environmental impact on the destinations but could contribute to the resource conservation for environmental protection; besides, facilitating the exchange and understanding between visitors and local citizens could enhance local economic benefits, social welfare, and employment opportunities. Taking ecotourism cognition as an independent variable and environmental impact sensitivity as a dependent variable and having environmental attitudes, location, and cultural difference as the harmonic variables, Lee (2011) revealed that ecotourism cognition would affect environmental impact sensitivity, and distinct environmental attitudes, location, and culture would also influence visitors' environmental impact sensitivity. Mobley et al. (2010) mentioned that ecotourism developed the maximum benefits with local knowledge and culture and, under the minimum environmental impact, provided the maximum satisfaction for visitors. Kim et al. (2011) pointed out the negative environmental impact of tourism on developing countries developing potential products to change the ecological resources of animals and plants in destinations. Han et al. (2011) proposed a series of negative impact caused by ecotourism activity in protected areas, including overcrowding, over development, unregulated recreation activity, pollution, wild species, and the use of powered vehicles. As a result, the following hypothesis is proposed in this study.

H3: Ecotourism cognition reveals notably positive effects on environmental impact.

## **Sample and measurement indicator**

### ***Research sample and object***

Tianmen Mountain Ecological Tourism Scenic Spot, located in Yongtai County, Fujian Province, Ge Zhen Creek Yeung, with the area of 6 square kilometers and the highest elevation of 828 meters, is named "Tianmen Mountain" because of a huge stone shaped like a door. Tianmen Mountain Ecological Tourism Scenic Spot connects with the routes of Tianmen Cave Scenic Group and Wanxi Canyon, with total 7 kilometers long, along which there is astonishing natural appearance. Tianmen Cave Scenic Group covers natural landscapes of Tianmen Cave, Guanyin Cave, Sun-Moon Cave, Tian Cliff, and Tian Bridge. It is worth mentioning that there is a novel finding by looking at the rocks above the underground river. Over ten-thousand-year stalactites naturally grow the shapes of Guanyin and Maitreya. Such natural creations are local wonders. The underground rive in Tianmen Cave Scenic Group and the special "pearls poured from a gourd" have been appraised as first-class touring spots. Tianmen Mountain Ecological Tourism Scenic Spot is therefore selected for this study, and the visitors, as the research subjects, are distributed 300 copies of questionnaire. Total 224 valid copies are retrieved, with the retrieval rate 75%.

### ***Test of reliability and validity***

Validity refers to the measuring tool being able to really measure the questions which a researcher intends to measure. Validity is generally divided into content validity, criterion-related validity, and construct validity. The questions in this study are referred to domestic and international research, and a pretest is preceded after discussing with the tutor that this questionnaire presents certain content validity. The entire structure causal relationship of ecotourism cognition, environmental attitudes, and environmental impact are tested with Linear Structural Relations Model, and the data input is based on the correlation coefficient matrix of above observation variables. The analysis results with Linear Structural Relations Model reveal the reasonable range of the overall model fit that it presents favorable convergent validity and predictive validity. According to Kerlinger (1986), the construct validity of a questionnaire could be tested with item-to-total correlation coefficient, i.e. reliability analysis. The acquired item-to-total correlation coefficient could be used for judging the questionnaire content. The item-to-total correlation coefficients of the dimensions in this study are above 0.6, showing certain degree of construct validity of the dimensions in the questionnaire.

To further understand the reliability and validity, both reliability and validity analyses are preceded. According to Guilford (1965), the higher Cronbach's  $\alpha$  reveals the better reliability. The formal questionnaire in this study is developed based on the standard, and the measured Cronbach's  $\alpha$  reliability coefficient appears in 0.80~0.90, conforming to the reliability range.

### **Analysis of experimental result**

#### ***Evaluation indicator of LISREL model***

LISREL model (linear structural relation), combining Factor Analysis and Path Analysis in traditional statistics and including simultaneous equations in econometrics, could simultaneously calculate multi-factor and multi-causal path. Regarding the evaluation of goodness-of-fit of a model, Bagozzi and Yi (1998) proposed to evaluate the preliminary fit criteria, overall model fit, and fit of internal structural of model. The research data are organized in *Table 1*. The preliminary fit criteria, internal goodness-of-fit and overall model fit of the model are explained as following.

From the analysis of the entire model in *Table 1*, the explanation of the four dimensions (environmental awareness, citizen participation, economic feedback, public fund) in ecotourism cognition to ecotourism cognition achieves the significance ( $t > 1.96$ ,  $p < 0.05$ ); the explanation of the three dimensions (cognitive component, affective component, behavior component) in environmental attitudes to environmental attitudes reaches the significance ( $t > 1.96$ ,  $p < 0.05$ ); and, the explanation of the three dimensions (environmental level, economic level, social and cultural level) in environmental impact to environmental impact achieves the significance ( $t > 1.96$ ,  $p < 0.05$ ). Apparently, the overall model shows favorable preliminary fit criteria.

In regard to the internal goodness-of-fit, ecotourism cognition and environmental attitudes (0.863,  $p < 0.01$ ) present positive and significant correlations, environmental attitudes and environmental impact (0.871,  $p < 0.01$ ) shows positive and remarkable correlations, and ecotourism cognition and environmental impact (0.886,  $p < 0.01$ ) also reveal positive and notable correlations. H1, H2, and H3 are therefore supported.



Regarding the overall model fit, the standards  $\chi^2/Df=1.751$ , lower than the standard 3, and  $RMR=0.006$  show that both  $\chi^2/DF$  and  $RMR$  are appropriate. Furthermore, chi-square value is sensitive to sample size that it is not suitable for directly judging the goodness-of-fit. However, the standards  $GFI=0.969$  and  $AGFI=0.921$  are higher than the standard 0.9 (the closer  $GFI$  and  $AGFI$  to 1, the better goodness-of-fit of the model) that this model presents better goodness-of-fit indicators.

**Table 1.** Analysis of LISREL model

Evaluation item	Parameter/evaluation standard	Result	t	
Preliminary fit criteria	Ecotourism cognition	Environmental awareness	0.741	8.33**
		Citizen participation	0.755	8.45**
		Economic feedback	0.738	7.69**
		public fund	0.691	6.42**
	Environmental attitudes	Cognitive component)	0.682	6.37**
		Affective component	0.705	8.16**
		Behavior component	0.713	8.21**
	Environmental impact	Environmental level	0.813	10.66**
		Economic level	0.802	9.47**
		Social and Cultural level	0.804	9.52**
Internal goodness-of-fit	Ecotourism cognition→environmental attitudes	0.863	18.73**	
	Environmental attitudes→environmental impact	0.871	22.45**	
	Ecotourism cognition→environmental impact	0.886	27.64**	
Overall model fit	$\chi^2/Df$	1.751		
	GFI	0.969		
	AGFI	0.921		
	RMR	0.006		

Note: \* stands for  $p<0.05$ , \*\* for  $p<0.01$ , and \*\*\* for  $p<0.001$ .

## Conclusion

The research results reveal the positive and significant effects of ecotourism cognition on environmental attitudes and environmental impact that ecotourists show higher concerns about the environment. Visitors with responsible environmental

attitudes would not make noise when finding exotic flowers and plants and directly touch fish, animals, and plants in the ecotourism process. The respect for and protection of the environment conform to the model of ecological sustainable development. In terms of the selection between environment sustainability and economic development, ecotourism appears positive effects on citizens by enhancing employment opportunities and improving public construction. The correlation between ecotourism and environmental impact therefore needs to be clarified. It would also impacts physical environment, economy, society, and culture. Moreover, “ecotourism cognition” indirectly affects “environmental impact” that visitors with better understanding of ecotourism cognition would perceive stronger impact on the environment and visitors with better understanding of ecotourism would enhance the environmental sensitivity. Regardless the citizen cognition of environmental impact, tourism activity in national parks could provide visitors with environmental education and enhance the environment cognition and ecological conservation to concern more about local communities.

### **Suggestion**

Aiming at the research results and findings, practical suggestions are further proposed in this study.

1. Visitors could bring profits in tourism areas, and each tourism area expects and dreams of more visitors. Local governments therefore are suggested to carefully use the resources to promote the spirit of ecotourism from “natural attraction and sustainable management”, excite visitors to visit ecotourism parks to increase local income, invite visitors joining in the ecology protection, and improve the environmental impact of visitors on ecotourism parks.
2. Establishing definite visitor centers allows visitors easily acquiring information about ecotourism parks. The introduction with DM or the visitor center personnel with systematical and complete promotion of ecotourism parks could have visitors clearly realize the characteristics of ecotourism parks and the correct position, rather than too many visitors crowding the same place and concentrating rubbish. Such a method could effectively separate visitors’ routes and indirectly reduce the environment impact of visitors on ecotourism parks.
3. The government is suggested to establish the feedback mechanism when developing the environment-protection ecotourism, including the increase of income and employment opportunities of local citizens. For example, visitors are offered to apply for environment or history interpreters, and local citizens have the priority in serving as interpreters and environment administrators to guarantee the employment opportunities and rights. Such conduct could educate visitors, protect the natural environment in ecotourism and the welfare of citizens, as well as enhance visitor s’ intention to visit and recommendation behaviors.

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## AHP–UTILITY BASED MODEL FOR EVALUATING THE COMFORT OF HOUSING: A CASE STUDY OF TAIWAN

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(Received 12<sup>th</sup> Aug 2016; accepted 12<sup>th</sup> Oct 2016)

**Abstract.** Buying a house for personal use is an infrequent investment for most people because of the high sales cost. Most buyers only make one housing purchase in their lives, most often for personal use. Real estate developers evaluate decisions for housing development projects often according to market- and sales-oriented factors. In addition to the fact that the industry involves fierce competition, real estate developers frequently neglect using healthy building materials and comfortable interior designs, focusing instead on a luxurious building facade to attract customers and the use of high-quality imported materials in the common spaces inside the building. To identify the factors affecting the comfort of living in houses and satisfy customer demands, this study combined two decision theories, the analytical hierarchy process and utility theory, to develop a customer health-oriented housing comfort assessment model. This model can be used to assess and compare the quality of living of various houses, providing housing agents with an evaluation tool that accounts for both sales and customer health that can be used in the evaluation process before a house is introduced to customers. Thus, the effectiveness of decision-making can be improved and the risk of investment reduced.

**Keywords:** *housing for personal use, real estate development, interior design, analytical hierarchy process (AHP), utility theory*

### Introduction

The building industry is a project-oriented industry (Voordijk et al., 2000), and project types (e.g., planning and design, construction, and vendor alliances) often vary among different building projects (Li and O'Brien, 1995). Because of the heterogenic construction process, the production and construction process in the building industry involve higher-than-normal risk compared with that in the general manufacturing sector, characterized by regularity and homogeneity. Furthermore, public building construction mostly involves customized products that are characterized by clear product features and specifications desired by customers (Kornelius and Wamelink, 1998); construction companies can simply adhere to the demands and specifications from owners. However, when real estate developers invest in houses, they must predict the demands of future customers, and when the housing plans do not receive customer approval, the house might not sell favorably, and housing vendors must reduce prices to attract buyers and avoid major losses. Therefore, real estate developers have much more operational risk than do construction companies that work only on a contractual basis.

Conventionally, production processes in the building industry are used to create the final houses and include services and considerations of customer satisfaction (Gruca and

Rego, 2005; Smith and Wright, 2002). Houses are a type of product in the housing industry. To improve customer satisfaction, real estate developers generally consider relevant factors that influence sales, such as the building facade, public space planning, construction and building material costs, housing prices (Chen et al., 2012), regional environmental conditions, repairs and maintenance, and services. However, using green building materials that benefit customer health and planning comfortable spaces inside the building are frequently neglected because such considerations are not easily comprehensible for most customers and also affect interior partition, construction costs, design and planning time, and construction time and methods. Therefore, regarding project development assessment, most real estate developers continue to develop and evaluate houses conventionally, neglecting factors that can facilitate improving the comfort of interior spaces.

The high concentration of CO<sub>2</sub> in the atmosphere worldwide in recent years, which has been ineffectively controlled, has already severely affected the environment (Bilgili, 2012), causing global climate changes and severe disasters caused by the climate (Caillaud et al., 2012). Environmental pollution is caused by the economic development of all countries and the destruction produced by humans. Thus, protecting the environment is a common responsibility of all people worldwide; only if countries carefully investigate the causes of pollution and create effective control and management policies can energy consumption and CO<sub>2</sub> emissions be lowered. However, no consensus regarding the reason for environmental problems has been reached, primarily because national economic interests and industrial and commercial economic interests are affected, but also because the habits in daily life will be influenced; these are still the reasons why various countries have been unable to attain CO<sub>2</sub> emission reduction agreement goals. Consequently, future environmental damage, greenhouse gas emissions, and climate change-induced catastrophes might severely harm human life and property.

The global greenhouse effect, combined with the heat island effect in Taiwan, caused the hottest temperature in 100 years to be recorded in Taiwan in September 2014. Taiwan, an island with high CO<sub>2</sub> emissions, possesses numerous highly polluting industries (e.g., thermal power production plants, chemical plants, oil refineries, steel plants, shipbuilding sites, cement plants, and industrial science parks) that require large amounts of natural energy sources such as oil, coal, and natural gas. These industries are the main cause of excessive pollution, hindering the resolution of air pollution and CO<sub>2</sub> emission problems. In addition to the aforementioned pollution sources, vehicles emit large quantities of waste gas daily in Taiwan. Among Taiwan's 111.54 million kiloliters of oil equivalent energy consumption in 2012, the energy and industrial, transport, agricultural, service, and residential sectors accounted for 45.25%, 11.89%, 0.89%, 11.04%, and 10.88%, respectively (Ministry of Economic Affairs, ROC, 2012). Most of the residential sector energy consumption is caused by construction machinery and the electricity and generator oil consumed during the building process. The residential sector also creates severe air and waste pollution.

According to the aforementioned descriptions, the severe air pollution problems in Taiwan and the global greenhouse and heat island effects that have caused existing problems and poor overall environmental quality in the country are evident. Currently, the goal of improving the comfort of home environments can be achieved only through the planning and design of living spaces, in which real estate developers should

consider the health of homebuyers and corporate social responsibility, thus establishing a corporate image. Therefore, to consider the interests of both real estate developers and customers and to lower investment risks, an objective assessment model must be established to facilitate decision-making. Conventional economic analysis methods and market surveys used by general real estate developers cannot be applied to assess the risks that the aforementioned factors, which are intangible and not easily quantified, might produce. In addition, housing vendors have long relied almost entirely on the subjective opinions of decision-makers as a basis for assessing project development (Ozsoy et al., 1996). However, this type of decision-making lacks an objective correction mechanism. Thus, in this study, we applied the analytical hierarchy process (AHP) and utility theory to establish an assessment model that enables decision-makers to make objective and rational decisions and that can be used to plan housing projects that more closely match customer demands.

### **AHP–utility-based model framework**

The decision assessment model established in this study has practical application value. The overall research framework content can be divided into (1) model development and (2) model application. The development of the model, which combines the features of the two multicriteria decision making (MCDM) models, AHP and utility theory, is summarized as follows:

- (1) Relevant literature on factors that influence housing quality was reviewed as a foundation for this study, and the criteria that corresponded to the requirements of the study model were further determined.
- (2) After the criteria for the assessment questions were determined, a hierarchy among the assessment factors was established, and we ensured that each criterion was independent.
- (3) Regarding the design, distribution, and recovery of the AHP questionnaires, AHP calculation formulae were used to obtain the relative size weighting values of the criteria.
- (4) If the recovered AHP questionnaires passed consistency tests, then the questionnaire data was considered valid. The criteria included the following: the consistency index (CI) was  $CI \leq 1$  and the consistency ratio (CR) was  $CR \leq 0.1$ .
- (5) The utility function of each factor was established, the quantization interval value was defined (convenient expression was the main consideration), and the effect values of the maximal, minimal, and threshold points were defined to serve as the utility function for solving each assessment factor.
- (6) From the relative weighting value and utility value of each assessment factor, the expected utility value (EUV) was obtained, completing the establishment of the assessment model.

The AHP–utility-based model is highly adaptive and convenient; the application of the model is summarized as follows:

- (1) The model can be used to assess the interior comfort of single households, as a tool for self-review provided to customers when purchasing houses, or as a reference for real estate developers and sales companies when establishing prices.
- (2) The model can be applied to assess the interior comfort of overall housing

development projects, providing a reference for design, planning, and modification as well as a reference for real estate developers considering overall sales establishing prices.

- (3) From the obtained relative weighting values, the importance of each assessment factor relative to other factors and significant influential relationships can be understood.
- (4) From the utility values of each assessment factor, the relationship by which the factors influence the overall EUV can be understood.

## **Literature review**

### ***Analytical hierarchy process***

The AHP, a MCDM model proposed by Saaty (1980), is commonly applied for decision analysis in management and other fields. Related research includes that on the maintenance selection problem (Bertolini and Bevilacqua, 2006) and redeveloping derelict public buildings (Hsueh et al., 2013). After the AHP was used to obtain data regarding the event to be evaluated through the questionnaires, the data that passed the consistency tests were further used to obtain the relative weighting values of each criterion through AHP calculations. Thus, the structured decision analysis method for the problem we investigated is provided.

### ***Utility theory***

In 1738, Daniel Bernoulli proposed utility theory, which is used to express the preferences and relative risk attitudes of people. A complex risk of uncertainty exists in decisions; therefore, the advantage of the utility theory is that it provides decision-makers with a quantified analysis mode that facilitates enhancing the objectivity of decisions. Relevant utility theory-related research in various fields includes evaluating household energy conservation performance (Hsueh, 2012) and build–operate–transfer projects (Yan et al., 2011). Regarding the application of the utility theory, we first defined the respective linear utility function of each criterion to convert each assessment situation into a quantified utility value.

## **Model description**

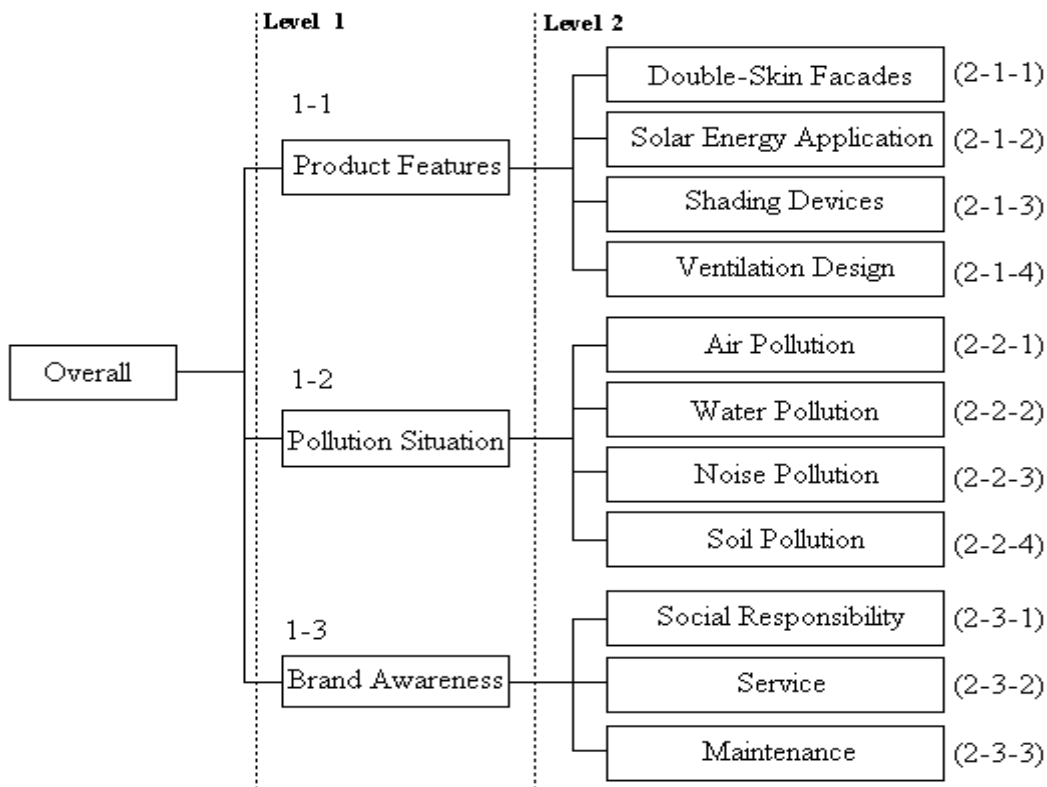
### ***Developing the initial criteria and hierarchy***

The purpose of housing projects is to improve quality of living and customer satisfaction with the goal of creating comfortable living spaces. According to Benett (1993), the planning and design of houses must satisfy the demands of customers. For example, the price of housing can be reduced to attract ordinary consumers with relatively low incomes, increasing the attractiveness of housing projects (Ziara and Ayyub, 1999). However, in addition to the fact that the planning and design of houses is competitive, Altas and Ozsoy (1996) indicated that residents increasingly emphasize problems with housing environmental quality. Therefore, the environmental conditions near houses are also a crucial factor influencing the attractiveness of housing projects. In their study on an assessment model for housing quality, Ozsoy et al. (1996) indicated that to increase residents' satisfaction, the comfort of the outdoor environment should be



emphasized in housing planning and design, and thus, the pollution level of the surrounding environment should also be considered. Furthermore, in addition to housing conditions and environment, the brand established by real estate developers over time is a crucial factor that can create customer confidence in houses. For example, Turpin (1995) indicated that the company brands of Japanese companies, cultivated over time by adopting customer satisfaction as an operational objective, were quality guarantees for the consumers; this guarantee of quality is an aspect in which Japanese companies differ from European and North American companies (Turpin, 1995).

According to the aforementioned discussion, we compiled three assessment dimensions for creating comfortable living spaces and satisfying the demands of housing customers: product features, pollution level, and brand awareness. To satisfy living space comfort demands, the relevant criteria in the product feature dimension include double-skin facades (Roth et al., 2007), solar energy application (Trappey et al., 2012), shading devices (Kotey et al., 2009), and ventilation designs. Relevant criteria that should be considered in the pollution level dimension are air pollution, water pollution, noise pollution, and soil pollution in the vicinity. The criteria that should be considered in the brand awareness dimension include corporate social responsibility, service, and maintenance. *Figure 1* shows a comprehensive hierarchy of each criterion in the three assessment dimensions.



**Figure 1.** Hierarchy of criteria

**Weighting value of each criterion**

We distributed 100 AHP questionnaires and recovered 52 valid questionnaires, the data from which were used to calculate the relative weighting values of the three assessment dimensions (*Tables 1-4*). We averaged the data values obtained from the valid questionnaires to compare ratios of each criterion presented in the tables. *Table 5* lists the weighting values of each criterion.

**Table 1. Weighting value of overall**

Comparisons of Product Features, Pollution situation and Brand Awareness()			
Criteria	Product Features	Pollution situation	Brand Awareness
Product Features	1	0.742	1.571
Pollution situation	1.348	1	1.545
Brand Awareness	0.636	0.647	1
Eigenvector	0.342	0.416	0.242

Consistency Index(C.I.)=0.006, Consistency Ratio(C.R.)=0.010

**Table 2. Weighting value of product features**

Comparisons of Double-Skin Facades(2-1-1), Solar energy application(2-1-2), Shading Devices(2-1-3) and Ventilation Design(2-1-4)				
Criteria	(2-1-1)	(2-1-2)	(2-1-3)	(2-1-4)
(2-1-1)	1	1.581	2.115	0.856
(2-1-2)	0.633	1	0.272	0.246
(2-1-3)	0.473	3.671	1	0.568
(2-1-4)	1.169	4.057	1.759	1
Eigenvector	0.292	0.102	0.224	0.382

Consistency Index(C.I.)=0.074, Consistency Ratio(C.R.)=0.083

**Table 3. Weighting value of Pollution situation**

Comparisons of Air pollution(2-2-1), Water pollution (2-2-2), Soil pollution (2-2-3) and Noise pollution(2-2-4)				
Criteria	(2-2-1)	(2-2-2)	(2-2-3)	(2-2-4)
(2-2-1)	1	2.105	0.497	0.914
(2-2-2)	0.475	1	3.091	1.208
(2-2-3)	0.494	0.324	1	2.388
(2-2-4)	0.523	0.828	0.419	1
Eigenvector	0.314	0.305	0.208	0.173

Consistency Index(C.I.)=0.69, Consistency Ratio(C.R.)=0.077

**Table 4. Weighting value of overall**

Comparisons of Social responsibility(2-3-1), Maintenance(2-3-2) and service(2-3-3)			
Criteria	(2-3-1)	(2-3-2)	(2-3-3)
(2-3-1)	1	1.105	0.415
(2-3-2)	0.905	1	0.476
(2-3-3)	2.408	2.10	1
Eigenvector	0.238	0.233	0.529

Consistency Index(C.I.)=0.003, Consistency Ratio(C.R.)=0.005

**Table 5. Weighting values of criteria**

Criteria	Level (1) $W_i$	Sub-Criteria	Level (2) $W_i$	Overall $W_i$	Overall Sequence
1-1	0.342	(2-1-1)	0.292	0.100	4
		(2-1-2)	0.102	0.035	10
		(2-1-3)	0.224	0.077	6
		(2-1-4)	0.382	0.131	1
1-2	0.416	(2-2-1)	0.314	0.131	1
		(2-2-2)	0.305	0.127	3
		(2-2-3)	0.208	0.087	5
		(2-2-4)	0.173	0.072	7
1-3	0.242	(2-3-1)	0.238	0.058	8
		(2-3-2)	0.233	0.056	9
		(2-3-3)	0.529	0.128	2

The sequence of the weighting values of each criterion in *Table 5* shows that the five criteria of ventilation design, air pollution, maintenance, water pollution, and double-skin facades significantly influenced the comfort of housing spaces. Among these criteria, ventilation design, double-skin facades, and maintenance increased the design, human resources, and construction costs of real estate developers. In addition, air and water pollution are regional environmental pollution problems; therefore planning and design as well as the use of green building materials and novel construction methods must be emphasized in developing housing projects and selecting a region with favorable environmental conditions.

#### **Utility function of each criterion**

In this study, we explored the comfort of housing spaces to achieve effective decision-making regarding housing project development and customer expectations. Therefore, a linear utility function was adopted and defined as  $u_i(y_i) = Ay_i + B$ ; to apply the utility theory for establishing the assessment model, the utility function of each criterion must first be determined. Every housing project has distinct conditions and situation; thus, each criterion will have a dissimilar assessment status, directly

influencing the parameter values ( $A$  and  $B$ ) of the utility function. Thus, the parameter values in the utility function of each criterion must be determined before calculating the utility value of each criterion. The calculation of  $A$  and  $B$  is described as follows:

- (1) In the assessment scope of each criterion ( $y_L - y_u$ ),  $y_u$  is the highest value and  $y_L$  is the lowest value. The assessment scope is defined according to the risk assumed by decision-makers and personal subjective preferences.
- (2) The optimal utility value in ( $y_L - y_u$ ) is  $y_m$ , and  $u_i(y_m)=1$ . The threshold point is  $y_T$ , and the turning point between positive and negative utility is  $u_i(y_T)=0$ .
- (3) Thus, equation (2) yields  $u_i(y_T)=A \times y_T + B=0$ ,  $B=-Ay_T$ , and thus, the relationship between  $A$  and  $B$  can be obtained:

$$u_i(y_m) = A \times y_m + B = 1, \quad A = \frac{1}{(y_m - y_T)}$$

- (4) The utility function of each criterion can be expressed as

$$u_i(y_i) = \left[ \frac{1}{(y_m - y_T)} \right] \times \frac{y_i - y_T}{(y_m - y_T)}$$

- (5) For each criterion, the utility function can be used to convert the assessment situation into a quantified utility value.

**Weighting value, utility value, and expected utility value**

Although the size relationship among the relative weighting values obtained from each criterion only describes the relative influence of each criterion on the living space comfort in this study, the product of the relative weighting value ( $W_i$ ) \* utility value ( $u_{ri}$ ) of each criterion is the EUV, a quantified assessment mode that can be used to compare size. Table 6 presents the relevant definitions used in this study and the obtained weighting value, utility value, and utility function of each criterion. The EUV equation is as follows:

$$EUV = \sum_{i=1}^n (u_{ri} \times W_i)$$

**Table 6.** weighting value, utility value and EUV

Criteria	$(W_i) * 100\%$	$y_L$	$y_u$	$y_T$	$y_m$	Utility Function ( $u_{ri}$ )	Worst	Optimal
(2-1-1)	10	0	100	50	100	$u(y) = 0.02y - 1$	-10	10
(2-1-2)	3.5	0	100%	50	100	$u(y) = 0.02y - 1$	-3.5	3.5
(2-1-3)	7.7	0	100%	50	100	$u(y) = 0.02y - 1$	-7.7	7.7
(2-1-4)	13.1	0	100	60	100	$u(y) = 0.025y - 1.5$	-19.65	13.1

(2-2-1)	13.1	200	0(PSI)	60	0	$u(y) = -0.017y + 1$	-31.44	13.1
(2-2-2)	12.7	100	0%	30	0	$u(y) = -0.014y + 0.4$	-12.7	5.08
(2-2-3)	8.7	140	0 dB	50	0	$u(y) = -0.02y + 1$	-15.66	8.7
(2-2-4)	7.2	100	0	30	0	$u(y) = -0.014y + 0.4$	-7.2	2.88
(2-3-1)	5.8	0%	100	60	100	$u(y) = 0.025y - 1.5$	-8.7	5.8
(2-3-2)	5.6	0%	100	60	100	$u(y) = 0.025y - 1.5$	-8.4	5.6
(2-3-3)	12.8	0%	100	60	100	$u(y) = 0.025y - 1.5$	-19.2	12.8
Expected utility value (EUV)							-141.15	88.26

The weighting values ( $W_i$ ) in *Table 6* were multiplied by 100% for convenient calculation and use. Regarding the threshold point definitions, the fuzzy range of air pollution was 0–200 PSI, because an air pollution level exceeding 200 PSI causes people to experience discomfort; a level of 51–100 PSI indicates mild pollution, and the air pollution threshold point was set to 60 PSI in this study. Regarding noise pollution, among the range of 0–140 dB generally heard by the human ear, people perceive 50 dB and below to be comfortable; sounds of 50–70 dB cause slight discomfort, and sounds exceeding 70 dB cause anxiety and trigger various other symptoms (Environmental Protection Administration, Executive Yuan, 2014). Therefore, the noise pollution threshold point was set to 50 dB in this study. As shown by the calculation results in *Table 6*, the worst situation EUV was –141.15 and the optimal situation EUV was 88.26.

### Case study

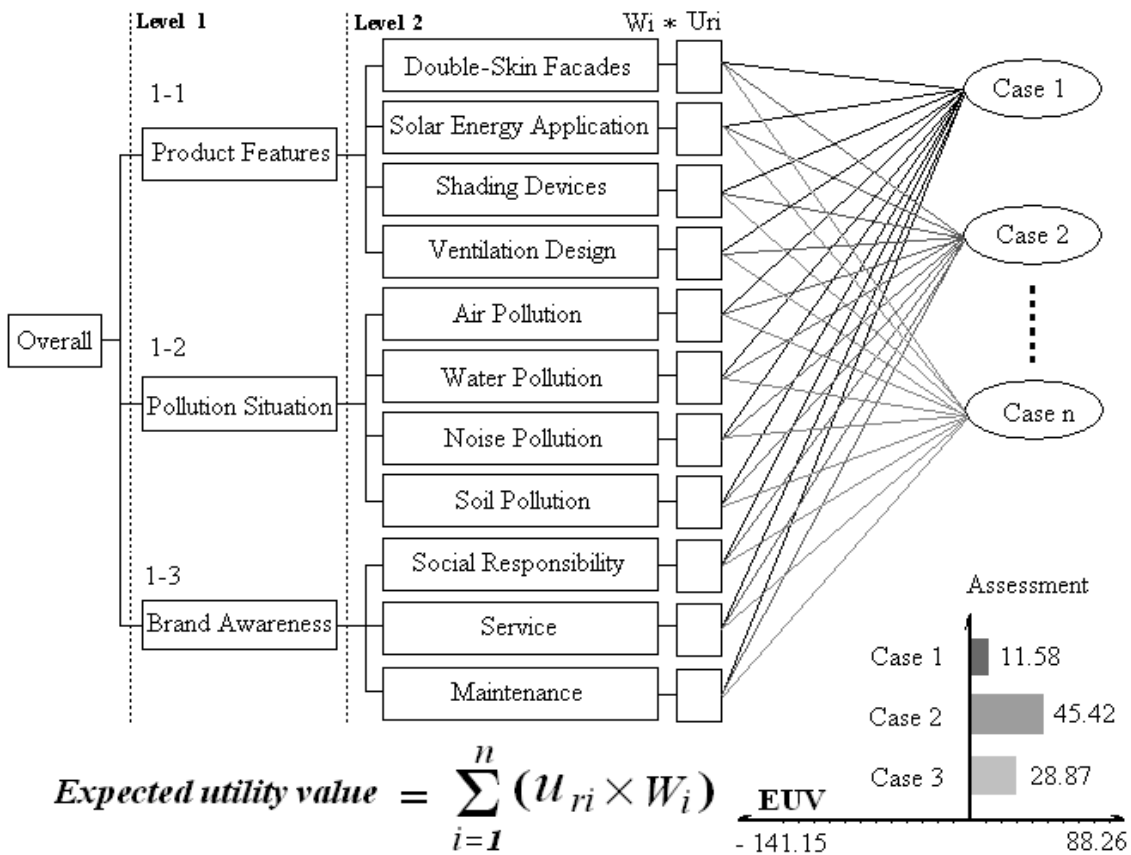
By calculating the weighting value and utility value of each criterion and the overall expected utility value, using the overall EUV, and applying the AHP–utility decision-making model, we obtained quantified values and compared their sizes. The values can be used by decision-makers as an auxiliary reference. In this study, we applied the model to three cases from Central Taiwan. The assessments were as follows:

- (1) The assessment results of each criterion in Case 1 revealed that except for the relatively favorable situation regarding noise and soil pollution, the conditions for the other criteria merely approached the threshold point. *Table 7* shows the overall living space comfort assessment values ( $y_i$ ) of each criterion.
- (2) Cases 2 and 3 involved assessments of development projects conducted by the same company in the same region. The case situations are identical, except that in Case 3, the planning of double-skin facades was not considered and the ventilation design involved no appropriate equipment plan. *Table 7* shows the overall living space comfort assessment values ( $y_i$ ) of each criterion for Cases 2 and 3.

Regarding the overall expected utility aspect of the housing comfort assessment results in Cases 1–3, the building facade and ventilation design facilitated improving the living space comfort in Taiwan, which is located in a subtropical region. In addition, based on the assessment results for Cases 2 and 3, the EUV of Case 2 was nearly double that of Case 3. The model application assessment results for Cases 1–3 are shown in *Fig. 2*.

**Table 7.** Assessment results for Cases 1–3

Criteria	$(W_i)$	Case 1		Case 2		Case 3	
		$(y_i)$	$(u_{ri}) * (W_i \%)$	$(y_i)$	$(u_{ri}) * (W_i \%)$	$(y_i)$	$(u_{ri}) * (W_i \%)$
(2-1-1)	0.100	50	0	100	10	50	0
(2-1-2)	0.035	50	0	80	2.1	80	2.1
(2-1-3)	0.077	50	0	80	4.62	80	4.62
(2-1-4)	0.131	60	0	80	6.55	60	0
(2-2-1)	0.131	0	0	40	4.19	40	4.19
(2-2-2)	0.127	0	0	20	1.52	20	1.52
(2-2-3)	0.087	0	8.7	30	3.48	30	3.48
(2-2-4)	0.072	0	2.88	20	0.864	20	0.864
(2-3-1)	0.058	60	0	80	2.9	80	2.9
(2-3-2)	0.056	60	0	80	2.8	80	2.8
(2-3-3)	0.128	60	0	80	6.4	80	6.4
(EUV)		11.58		45.42		28.87	



**Figure 2.** Schematic of the assessment results for Cases 1–3

## Conclusion

Ensuring the comfort of living spaces is the basic cognition and responsibility of real estate developers. For homebuyers, such comfort facilitates quality of life in the home and is also a fundamental right. However, because of cost and market competition factors, real estate developers frequently disregard planning and designing high-quality, comfortable living spaces. The results of this study revealed that regarding the influences on housing space comfort, corporate image as well as planning and design must be considered in addition to regional environment. Planning and design, green building materials, and novel construction methods can be adopted to overcome the congenital problem of poor environmental quality. Thus, the comfort of living spaces can be enhanced.

Taiwan is located in a subtropical region and has developed industries; moreover, residents extensively use cars and scooters daily, creating excessive energy consumption and large amounts of warm gas emissions, which cause severe air pollution and heat island effects. Therefore, the extensive use of air conditioning and the increasing use of electricity are serious unresolved problems in Taiwan in the summer. Regarding an effective solution for the problems of housing space comfort in Taiwan and household energy consumption, if real estate developers can comprehensively consider and attain high quality in the planning and design stage of construction, then the quality of living can be improved and environmental pollution can be reduced. Otherwise, subsequently improving housing spaces will result in construction waste and waste gas and hot gas emissions that influences neighboring households. The results of this study indicate that the essential question of residential spaces is overlooked because real estate developers lack social responsibility. In addition, homebuyers lack professional knowledge, causing them to be deceived in the long term. The AHP-utility decision-making model can provide real estate developers and homebuyers with a tool for assessing the comfort of housing spaces, facilitating an overall increase in housing quality in Taiwan.

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# THE IMPACTS OF SITE SELECTION AND PLANNING OF A HISTORIC SETTLEMENT ON A SUSTAINABLE RESIDENCE

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** To find a sustainable living environment, ancestors looked to the site selection method of traditional Feng Shui from ancient China, evaluating and selecting the place most suitable to live in. The current location, environmental conditions, and building clusters of the Hua Zhai Settlement meet the most fundamental criteria of site selection. Further analysis of the local weather data from the last thirty years highlighted the most significant weather factor impacting Hua Zhai Settlement: wind. This factor is used in Computational Fluid Dynamics (CFD) wind environmental simulation, the results of which show that settlements that adhere to the most basic site selection principles are able to provide residents with a more comfortable living environment, allowing people to live sustainably. This proves that Feng Shui is indeed the accumulation of rules governing our living experiences.

**Keywords:** *traditional settlement; CFD; Feng Shui; wind environment; sustainable planning*

## Introduction

To look for a sustainable residence environment, people from the past relied on their knowledge and experiences in traditional Chinese geomancy to screen, evaluate, and select a suitable location to live in. (He, 1995) Site selection includes analysis of the terrain, location, and direction to ensure the residents' quality of residence and level of comfort, which, in turn, affect health, good fortune, etc. The location of the Hua-Zhai settlement is closely related to Chinese geomancy knowledge, which was initially used by the residents for site selection. They believed that the place is suitable for settlement and this belief has proven true through the centuries.

The location of the historical settlement is closely associated with the knowledge of Feng Shui, which is part of Chinese tradition (Yi et al., 1996; Makand Ng, 2005). At initial stage of the development of historic settlement, usually there was a group of residents with blood relationship who consulted Feng Shui Masters to find a proper environment for sustainable residence in order to construct a huge amount of orderly arranged buildings with guaranteed residence quality.

With the climate change and the development of the times, the surrounding environment of Hua-Zhai settlement has already changed. A few of the low buildings in the settlement were removed and changed into buildings made of reinforced concrete and at a height of 2 to 3 stories. In order to analyze the impacts of initial site selection criteria of historic settlement and the planning of building groups on the sustainable residence, the oldest cadastral data and maps currently preserved will be

used based on current status of Hua-Zhai settlement to restore the building groups and surrounding environment in early days of Hua-Zhai settlement while analyzing the oldest weather data. The analysis of 30 years of meteorological data has revealed that “wind” is the main climatic characteristic. Therefore, the CFD wind environment simulation has been implemented to analyze the relationship between wind and the site selection and planning of Hua-Zhai settlement.

Wind environment is one of the main factors affecting human comfort for pedestrians (Cheng and Wang, 2005; Hsieh et al., 2014). The wind field affecting the comfort of pedestrian is called pedestrian wind field, which generally refers the wind field 1.5 to 2m above ground surrounding any building. Building configuration (e.g. height, width, arrangement and density) has been shown to have significant influence on wind at ground level. Wind speed affects pedestrian wind comfort and wind safety. Many countries have established standards for the speed of pedestrian wind fields in the light of the modern buildings (Mochida and Lun, 2008). The assessment standards of these countries are mostly based on Beaufort scale with some modification before being developed as regulations. The regulations are mainly for the maximum wind speed in the wind environment for protection against wind hazards. The other part is setting the evaluation criteria for assessing wind comfort as well as coming up with the minimum tolerable range of wind speed values. Disregarding gender and activity types, studies in Taiwan on the comfort level of pedestrian wind field consider 6-7m/s as the maximum wind speed range in terms of pedestrian wind field comfort (Guo, 2011). The gust speed 8m/s is the upper limit of pleasant wind speed among residential areas and wind hazard sensitive areas in Taiwan (Ding and Chu, 1999). According to the classification of Beaufort scale, an area with a wind speed less than 0.3m/s is in windless state, so the wind speed of a comfortable pedestrian wind field should at least be 0.3m/s.

In addition, wind speed will affect the thermal comfort of human body (Hsieh et al., 2016). Proper natural ventilation will help human body exclude heat thus contributing to health and physical and mental comfort. In order to improve the quality of urban living and health environment of residents, Hong Kong government has been putting a great deal of emphasis on the natural ventilation of outdoor environment in recent years, and it has commissioned The Chinese University of Hong Kong to carry out a research on stipulation of air flow regulation. Relevant research results have revealed that, in a typical summer day, when air temperature is 27.9 and relative humidity is about 80%, wind speed of 0.6 to 1.3m/s is required to achieve neutral thermal sensation (Yuan and Ng, 2011).

In this study, CFD has been used as the analytical tool. CFD has been increasingly used to assess pedestrian-level wind conditions in urban areas (Blocken and Persoon, 2009; Blocken et al., 2012; Hsieh and Huang, 2016). The discussion focus of most essays on modern cities is on the microclimate (see Nugroho et al. 2007; Li, et al., 2012; D’Agostino et al., 2013). However, in contrast, there are much fewer researches on historical settlements’ microclimate. Tang et al. (2012; 2014) provided simulations of the wind environment and the thermal environment with the general terrains of the historical settlement. The above-mentioned literature has not carried out detailed CFD simulation of the terrain and building groups. It has also not also used CFD in comprehensive discussions about the relationship between environmental conditions, historical settlement selection, and planning of the building groups. Therefore, in this study the 3D model of topographic environment and building groups of Hua-Zhai

settlement in early days has been composed, and the impacts of topographic environment conditions of site selection and building groups planning of Hua-Zhai settlement on sustainable residence has been investigated based the CFD analysis of wind field in the settlement.

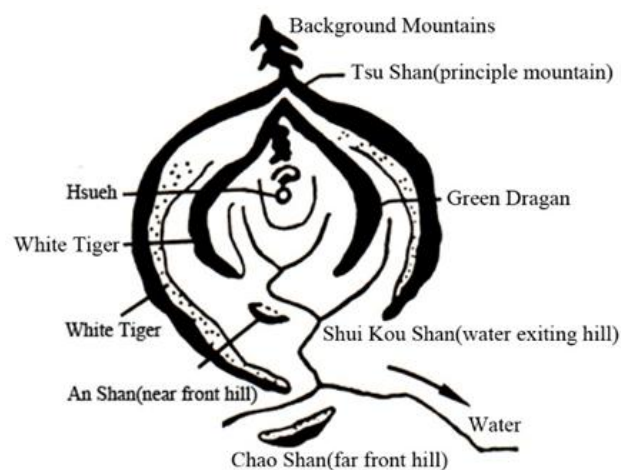
## Materials and methods

### Study area

Hua-Zhai settlement is located on Wangan Island of Penghu County, Taiwan. The residents of Hua-Zhai settlement have kinship because a lot of people moved here together during the Ming dynasty. This settlement has been constructed for about 300 years till now and it covers a total area of 5900 m<sup>2</sup>. There are 160 buildings in total and among them, 52 historical buildings are well preserved. In 2004, World Monuments Watch announced that Hua-Zhai settlement was on the List of 100 most endangered sites.

The Taiwan Strait fronts Hua-Zhai settlement, with the five hills surrounding it on the other sides. (Fig. 2) These hills are respectively Hutou Mountain (Spot A), Tiantai Mountain (Spot B), Fengmen Mountain (Spot C), Hongmuqian Hill (Spot D) and Jianshanzai (Spot E). The average height of the five hills is the elevation of 29m. Because the natural landscape is like a flower, it is called as “Hua-Zhai”. Hua in Chinese means flower. There is a small raised hill in the center of the settlement. Its shape is like a bud and so is called “Hua-Si.”(Spot F). The residents consider the Hua-Si as a sacred land such that there should not be any farming or housing at this location, which is also called the Hsueh. It means central site in traditional Chinese Feng Shui theory.

In Feng Shui theory, a good spot must be a place for “Chi” to be accumulated, and also an intersection for Yin and Yang. In terms of the features of topographic environment, a fine place must be in front of hills (indicating Yin) and behind a body of water (indicating Yang) as a space surrounding by layers of mountains and waters. This space is called “Ming Tang”, and the center of “Ming Tang” is “Hsueh”, which is the best Feng Shui spot filled with the most “Chi” (Fig. 1). The topographic map of Hua-Zhai settlement is similar to the Feng Shui map, where layers of hills surround the Hua-Zhai settlement, and the Hua-Si is an elevated center of the spot surrounded by hills, which is also the Hsueh of Hua-Zhai settlement.



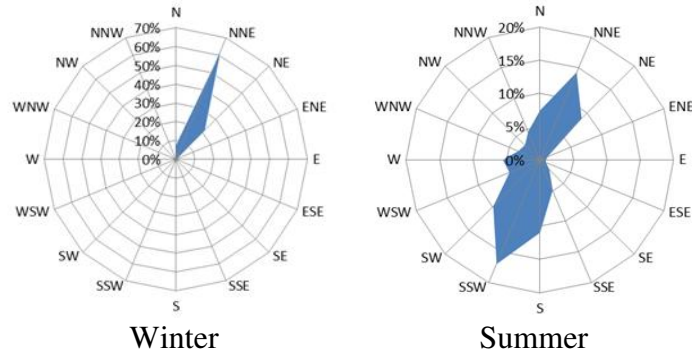
**Figure 1.** A fine place as defined by Feng Shui



**Figure 2.** 2008 topographic map of Hua-Zhai settlement overlaid onto the orthophoto map

Penghu Weather Station is located on Wangan Island and was built in 1896. Due to the lack of detailed records of meteorological observation as well as meteorological data in 1896-1960, it in 1961 Penghu Weather Station had its earliest and most complete meteorological data. As a result, the thirty-year meteorological data from 1961 to 1991 was analyzed in this study.

Penghu Islands belong to subtropical monsoon climate and their average annual rainfall is around 1000mm. The seasons of the rainfall are unevenly distributed. An analysis of the thirty-year long average temperature shows that winter is from November to March, and the average temperature at 18.3°C; summer is from June to September and the average temperature is 27.8°C. The strong winter monsoon wind is its primary weather feature. There are strong winds around one third of the year. In winter, the average wind speed reaches around 7.15 m/s. The main wind direction is NNE and the maximum wind speed reaches 24.6 m/s. In summer, the average wind speed is 3.64 m/s and the primary wind direction is SSW (*Fig. 3*). There is a great gap between the average wind speed in winter and summer. Monsoons not only impact the growth of crops and forest, but also cause a higher salinity of the soil, which becomes unsuitable for the growth of plants. As a result, there are only low grassland and shrubs on Penghu Islands. Wangan Island, the location of Hua-Zhai settlement, is surrounded by the sea. The terrain of the island is flat and there is no mountain to protect it, which leads to the suffering of the island from the wind damage throughout the year. Due to the impact of years of suffering from wind damage, the grassland, therefore, has become the most common landscape in the Hua-Zhai settlement.



**Figure 3.** Wind rose diagram in Penghu weather stations from 1961-1991

## Methods

### *Reconstruction and 3D modeling*

In order to understand the original conditions for the selection of the settlement, the study uses historical data and information on current status to recover the original appearance of the settlement, including the terrain and building groups. Analysis is conducted after the creation of the restoration model.

Historical data used in the restoration process is categorized into maps and cadastral information. Maps include the 1895 Japanese Army survey maps (Scale: 1/50000), 1904 "Taiwan Fort Maps" (Scale: 1/20000), 1926 "Taiwan Topographic Maps", 1960, "Taiwan Economic Planning Version Topographic Map" (Scale: 1/25000), and 1980 "Aerial Survey Map" (Scale: 1/5000). Cadastral data include the 1898--1945 "the land registration book" on changes in land ownership, land division, merger, and sale or lease of lands, as well as the 1913 cadastral blueprints used until 1991 (Scale: 1/1200), totaling 11, and cadastral maps from 1991, which have been digitalized but have not been re-surveyed (Scale: 1/3500).

In order to make up for the inadequacy of the abovementioned historical data, the study conducted a survey on the current conditions of Hua-Zhai settlement in 2012, primarily focusing on the use and division of the land, as well as the building groups and status of the surrounding topography. The study drew a restoration map based on the information gathered at the site. The restoration map is made into a 3D model, which then converted into an STL file and imported into the CFD software for further analysis. Due to the limitations in historical data and current information, the earliest recovery time for Hua-Zhai settlement is 1913. The procedure for settlement restoration and 3D model construction is as follows:

1. Topographic map restoration: The 1895 and 2008 topographic maps are overlaid on top of each other; this method is used for terrain restoration. First, the result of the overlay is partitioned and aligned for comparison and correction. A new recovery topographic map is then drawn based on these corrections, the contour lines of which are made into a 3D terrain model.

2. Cadastral map restoration: Cadastral maps of the Hua-Zhai settlement were used from 1913 to about 1970. The government agency in charge of these maps have repeatedly recorded and revised the original version to reflect changes in land type as well as in the status of ownership. Consequently, the study has used the information on these maps including those on land mergers, land divisions, and changes in land

ownership. The earliest restoration can be traced back to the 1913 cadastral and land entries of Hua-Zhai settlement.

Government agencies have made notes and revisions on the original image many times to show changes in the land, change in ownership, and other types of information. Consequently, the 1913 cadastral data and land headings are restored through land numbers showing land mergers and divisions, as well as information on the changes in land ownership.

3. Restoration of the building groups location delineation and roads: Using the "land accounts" as a basis, to find the building sites and land headings for the roads, which will serve as restoration bases for the location and number of buildings. Then, based on the information on the land headings and cadastral maps, find the roads and fields marked on the 1913 cadastral restoration map before nesting said map and the restored 3D terrain model.

4. Restoration of the building groups: First, conduct a survey on the age and measurements of the existing buildings and make a configuration diagram of the building groups constructed about 1913. Then, statistical data of the exterior architectural dimensions of the existing buildings is used to determine those of the buildings that do not exist anymore. Afterwards, based on the breadth and depth of the land on the restored cadastral map, build a 3D model in accordance with the positions shown on the post-restoration cadastral map.

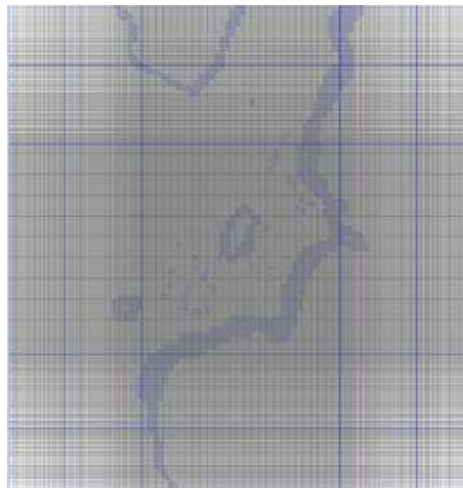
#### *CFD simulation*

In this study the environment surrounding Hua-Zhai settlement and the building groups within the settlement in 1913 have been restored based on cadastral maps and topographic maps and converted into 3D models to be imported into CFD for simulating the wind environments of Hua-Zhai settlement during winter and summer. The geometry and the boundaries simulated by CFD are shown in *Table 1*. The scope of simulation is centered on the Hua-Si of Hua-Zhai settlement and extended outward by 400m. The overall simulative boundary condition is set to be 800m (N-S) × 800m (E-W) × 250m (altitude) (*Fig. 4*), and with Hua-Zhai settlement building group as the area of focus with the scope of 400 (N-S) × 500m (E-W). The most proper mesh size is located in the focus region. Because the width of the roads in Hua-Zhai settlement is 2-3 meters, the X and Y axes of smallest grid in the focus area is 2m x 2m. Extended outward from the focus region, the mesh size gradually grows larger (X axis grows to 5 and 8m; Y axis grows to 8 and 24m). The mesh size of the vertical axis of the focus region is 0.5m, also growing larger as it extends from the focus region. The amount of the meshes of this simulation is 4,498,848 in total. Wind speed as a function of height above the ground was assumed to follow a power law distribution. The maximum terrain elevation within the simulation scope is 20.5m, such that the index value ( $\alpha$ ) is set to be 0.25 in accordance with the Modified Rules of Taiwan Building Wind Resistance Design Regulation and Specification (Construction and Planning Agency, 2014). It is generally applied to small towns or areas with many obstacles at the heights of residential house (10 to 20 m) or higher, which is applicable to the conditions of lands within the simulation scope of Hua-Zhai settlement.

Next, to discuss winter and summer, the simulations of winter (November to March) and summer (June to September) are respectively conducted. The prevailing wind in winter is the NNE monsoon and the wind speed is 7.15m/s. The prevailing wind in summer is the SSW monsoon and its wind speed is 3.64m/s.

**Table 1.** CFD simulation settings

<b>Inflow direction</b>	NNE(Winter), SSW(Summer)
<b>Velocity (m/s)</b>	7.15m/s(Winter), 3.64m/s(Summer)
<b>Boundary volume(L×E×H)</b>	800m×800m×250m
<b>Mesh number</b>	≈ 4498848
<b>Reference height (<math>\delta</math>)</b>	25.28m
<b>Power law profile (<math>\alpha</math>)</b>	0.25
<b>Roughness height (Zb)</b>	20m



**Figure 4.** CFD simulation model grid

## Results and Discussion

### *Principles and impact of site selection*

The most basic principles for site selection found in the ancient books: "Tao TeChing," the "Sheng Ma Chapter" of "Guanzi," and the "Book of Odes". The principles include "Qi exists where the place is surrounded by hills and embraced by watercourses," "Ward off the yin while embracing the yang," "backed by hills while facing watercourses," and "High in front and low at the back." Using these principles to analyze the terrain of Hua-Zhai settlement and its surroundings, it is known that the settlement faces the Taiwan Strait (facing watercourses), is surrounded by hills (with the back to the hills), as if the back of the settlement embraces a virtual space; this configuration adheres to the Feng Shui criterion of "surrounded by hills and embraced by watercourses." In fengshui, the mountains alludes to the "yin" and the body of water alludes to the "yang." The location of the Hua-Zhai settlement adheres to the principle of "warding off the yin while embracing the yang," which can also be described as "backed by hills facing the watercourses." From the ancient books, it can be comprehended that a location with these conditions can "hide the winds to keep the vital energy." These words refer to being able to surround the winds and keep the "qi." Because "qi" has been retained in the place, it becomes a location very suitable for living. Furthermore, the area located in the direction in which Hua-Zhai settlement faces the sea is low-lying. The terrain gradually becomes higher towards the back of the

settlement, eventually forming hills. This adheres to the criterion "High in front and low at the back."

In addition, in terms of the principles for the wind, the ancient books describe that the place needs to have wind and that the wind speed can neither be too strong or too weak. Places where the wind blows gently are best suitable for living. Wangan Island is beset by strong monsoon winds during winter. The average wind speed is 7.15 m/s, with maximum average wind speed of 24.6 m/s, making it difficult for plants to grow. Moreover, the growth and height of plants are repressed because of this. However, plants and crops can be planted in the Hua-Zhai settlement and from the residents' oral history information, it is found that the strong winds could be heard but not felt as residents walked through streets and alleys of Hua-Zhai settlement during winter. In the hot summer afternoons, the wind blew through the settlement streets. From the status survey conducted by the study, it is found that, in the afternoon, residents often sit in shady areas between alleys to rest and enjoy the cool outdoor breeze. Thus the speculation those local residents looked for wind and its appropriate speed to ensure that they have a place suitable for long-term residence.

### ***Simulation Analysis***

Affected by surrounding topography, the buildings in Hua-Zhai settlement are distributed along the slow slope in two clusters. Most building groups and main streets are in the main cluster located at an altitude of around 2.3m, while other building groups and streets are scattered among altitudes of 4.7-6.3m. With "wind" being the major local weather feature, CFD wind environment simulation is implemented for analyzing the 1.5 m pedestrian wind field of Hua-Zhai settlement during winter and summer in order to understand the relationship between environment conditions and the site selection and planning of historical settlement.

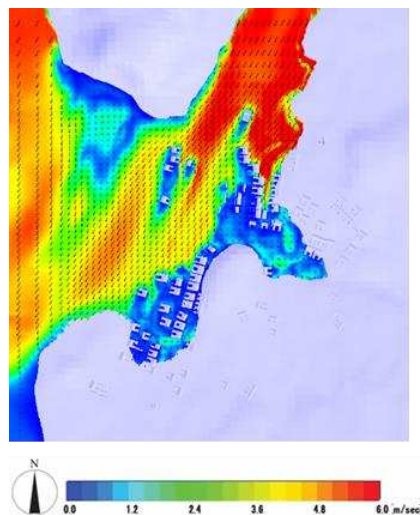
In winter, the main wind direction in Hua-Zhai settlement is NNE, as confirmed by the simulation results (*Figs. 5, 6, 7*). The winds are blocked on the northeast side by Hutou Mountain (*Fig. 1 Spot A*) and Fengmen Mountain (*Fig. 1 Spot C*). As the winds near the settlement, they grow weaker due to the topography. At the place within the building group, where elevation is at 3.2 meters, as the winds approach the settlement square, the pedestrian wind speed at an altitude 1.5m is reduced to 3.3 - 4.2 m/s, while that on the road is reduced to 0.6-1.2 m/s. For the other buildings, which are built along the terrain, distributed at an altitude of 4.7-6.3m, as well as roads distributed at an altitude of 4.7m, pedestrian wind speed goes down to 1.5 - 3 m/s. For roads distributed at an elevation of 6.3m, pedestrian wind field goes down to 1.8-3.9 m/s. From this information, it can be concluded that the settlement is able to avoid the strong winds during winter. The wind speed of the pedestrian wind field within the settlement is between 0.6 - 4.2 m/s. Without considering going out for a walk, temporary stay, or gender factor, the wind speed value of the settlement in winter is within the comfort range of Taiwan's pedestrian wind field.

In summer, the main wind direction is SSW. Because Hua-Zhai settlement faces the Taiwan Strait with its back surrounded by numerous small hills, the building groups are built along the terrain. The primary direction of the summer winds is SSW. The winds come from the side facing the sea due to the position of the settlement location. Moreover, because the street and major wind direction form a narrow angle of approximately 5 - 22.5 degrees, the side facing the wind is able to receive ventilation. From the simulation results (*Figs. 8, 9, 10*), it can be seen that majority of the building

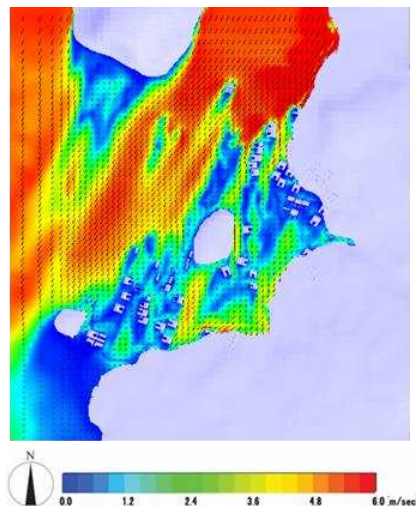


groups are located at an elevation of 2.3m; the wind speed of the pedestrian wind field of the streets and the settlement square ranges from 0.7 - 2.6 m/s. For other buildings distributed at an elevation of 4.7 m, the wind speed of the pedestrian wind field on the street ranges from 1.5 - 3.3 m/s. During the summer, the speed of the summer winds ranges between 0.7 - 3.3 m/s. the smallest wind speed value is higher than 0.6m/s, which exceeds the basic ventilation standards of the settlement environment. This improves the tolerance residents have for the outdoor temperature.

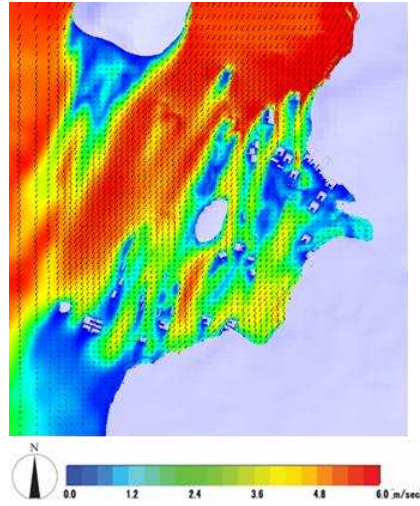
Due to the topographical environment and the spatial arrangement and planning of Hua-Zhai settlement, including the arrangement of the buildings and the location of the settlement, Hua-Zhai settlement can block winter monsoon winds effectively during winter and provide a good pedestrian wind field in the settlement. The opening between the hills surrounding the settlement and the sea front of it as well as the way the roads are laid out allow the southwest monsoon winds to blow into the settlement in the summer. Moreover, the angle produced by the streets and the wind direction not only allows ventilation, but it also increases wind speed.



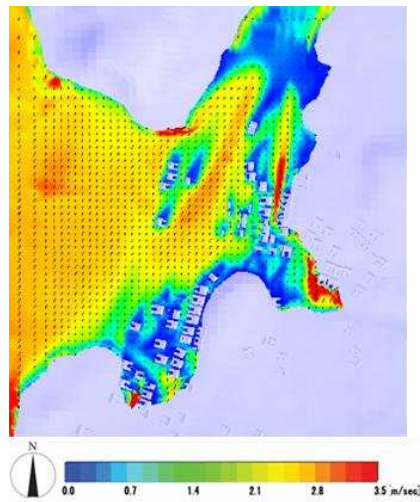
**Figure 5.** The simulation of 1.5m wind field at an elevation of 2.3m in winter



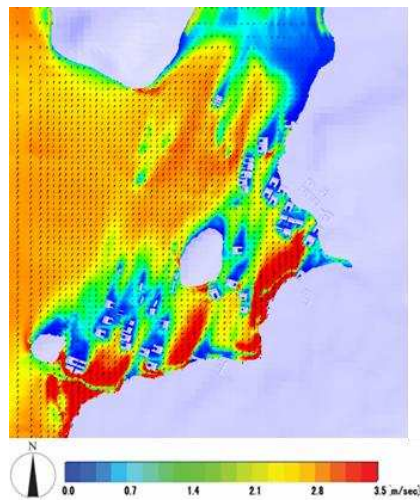
**Figure 6.** The simulation of 1.5m wind field at an elevation of 4.7m in winter



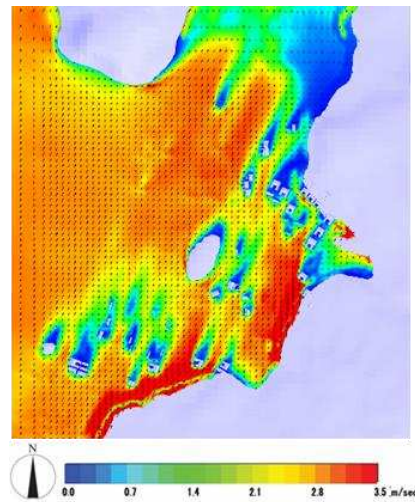
*Figure 7. The simulation of 1.5m wind field at an elevation of 6.3m in winter*



*Figure 8. The simulation of 1.5m wind field at an elevation of 2.3m in summer*



*Figure 9. The simulation of 1.5m wind field at an elevation of 4.7m in summer*



*Figure 10. The simulation of 1.5m wind field at an elevation of 6.3m in summer*

## Conclusion

To create ideal living environments, people of ancient China use their life experiences to come up with knowledge in fengshui or geomancy, making it a basis for environmental norms and assessment system. Finding a suitable place of residence by applying the fengshui's site selection rules allows for sustainable living. Site selection methods include analysis of the terrain as well as analysis of the location and direction not only to ensure the quality of living and comfort of the residents but also to guarantee health and good fortune.

Initially, residents of Hua-Zhai settlement used their knowledge of fengshui to perform site selection, believing that this location was suitable for residence and eventually settling here. The study used the basic criteria for site selection to analyze Hua-Zhai settlement and its surrounding terrain. The site adheres to the fundamental site selection principles of fengshui including "Ward off the yin while embracing the yang," "Backed by hills while facing watercourses," and "High in front and low at the back." Because wind is the most significant factor affecting the quality of living of the residents, after comparing historical data, residents' narrations, and status survey data, it is ascertained that the site adheres to the site selection criteria for wind. Moreover the study uses 30 years of meteorological data and CFD software to simulate the wind environment of Hua-Zhai settlement. From the CFD simulation results, it is known that, affected by the terrain, the wind speed of winter monsoon winds is reduced before entering the settlement, allowing residents to grow crops and to enable residents to walk on a comfortable pedestrian wind field during winter. In addition, the building groups within the settlement are built along the gentle slope and are arranged in groups. This irregular configuration is conducive for the cluster buildings to avoid the wind. Furthermore, the settlement is surrounded by small hills, with the direction facing the sea the only opening. This allows the summer winds to blow along the terrain into the settlement from the sea. Because there is a narrow angle formed by the streets and the wind direction, this makes the winds stronger and allows the settlement to maintain ventilation. The wind speed values exceed the minimum ventilation standards for outdoor environment. From the abovementioned, it is known that Feng Shui is an accumulation of rules for living life. Based on the site selection principles,

our ancestors have been able to find the Hua-Zhai settlement to live in an environment with harsh climatic conditions. Because in Hua-Zhai settlement, they are able to find shelter from the winds during winter and maintain ventilation during summer, the residents have a comfortable living environment, enabling them to settle and live here for many centuries.

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# IMPLEMENTING SMART GREEN BUILDING ARCHITECTURE TO RESIDENTIAL PROJECT BASED ON KAOHSIUNG, TAIWAN

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** In order to be in line with the thought of the general public with regard to the implementation of Green Architecture on Smart Residential Project, this study is based on the implementation of the Smart Green Architecture of congregate residual buildings in Kaohsiung as the main strategic promotion topic. In addition, this study realized the collection and consolidation of Smart Green Building promotion policy worldwide and carried out comparative analyses of both domestic and oversea Smart/green residential building's energy saving technology. Furthermore, we consolidated 9 major topics and relevant 38 technical methods on residential environment ecosystem, daily passive energy-saving, daily proactive energy-saving, healthy indoor environment, community waste water and garbage treatment, smart door security management, smart environmental monitor system, smart health management, and smart entertainment sharing. Moreover, the application of Likert-type scale is to obtain significant information and to investigate the perception for both construction supplier and general public on the implementation of Smart Green Building Architecture of Residential Project. It simultaneously explained the importance of pro-environmental which results from the implementation of Smart Green Building Architecture. This also assists the promotion of the localized Smart Green Residential Architecture policy.

**Keywords:** *smart residential, smart architecture, green architecture, Likert-type scale, pro-environmental*

## Introduction

The architecture industry has been recognized with high pollution and high energy consumption and is an environmental unfriendly industry. The Green Architecture is an effective practical method to improve the environmental damages caused by the architecture industry (Hsueh, 2013, 2015; Zhao et al., 2015). Green Architecture not only involves issues such as green design, green procurement, green construction skill and legal matters but also affects the overall skill set of the architecture industrial chain and users' habituation (Goralnik and Nelson, 2011; Logman et al., 2015) and acceptance issues (Brunhaver et al., 2012; McLaughlan, 2007). Therefore, architecture design, procurement, construction and management are only confined by state-owned constructions. Moreover, Green Architecture regulations lack a mandatory restriction on privately-owned projects. Therefore, the implementation of Green Architecture and Smart Architecture in Taiwan is unable to identify the effectiveness of energy-saving and carbon emission reduction as well as reduction in environmental pollution. Therefore, the architecture industry in Taiwan is still an industry which emits high CO<sub>2</sub>, and high CO<sub>2</sub>, causes issues such as environmental damage, greenhouse effect, abnormal weather, and climate change etc. (Khan et al., 2016; Heidari and Pearce, 2016).

As a result, we shall not neglect climate change issues. The nature of Green Architecture is a behavior of mitigation to climate changes (Nema et al., 2012). An agreement on the reduction of CO<sub>2</sub> emission has been signed during the Climate Summit 2015 which took place in Paris. As a result, the architecture industry shall actively face the subject of green transformation. To this extent, this helps to prevent the operational impact on business and overall economic status if carbon emission taxation takes place in the future (Rafindadi, 2016).

The current project on the implementation of Smart Green Architecture in Taiwan is the Green Architecture technology from the past and implement the smart control technology in the mind of the life style of the general public. In addition, we can apply the result of advanced technology software and energy-saving Green Architecture to achieve the promotion of the Smart Green Architecture industry (Chen and Kang, 2016; da Silva et al., 2015; GhaffarianHoseini et al., 2013; Toure et al., 2015; Mihelcic et al., 2007). Furthermore, we should provide health and safety, convenience and comfortability, the energy-saving and environmental-friendly concept to the general public. Moreover, to achieve the goal and the development of technological industry. The promotion of smart and green technologies should be educational in nature, reaching out to a wide range of parties and allowing them to participate in the progress of the technologies (Kua et al., 2002; Hurtado and Hunte, 2007; Pierchala et al., 2016). Therefore, how to customize the policy which would be most suitable for Kaohsiung in promoting Smart Green Architecture and the understanding of construction suppliers and general public's perception towards the policy are the main purpose of this study.

In order for the promotion of the Smart Green Architecture to meet with the thought of the general public, this study has consolidated relevant literatures, proactive energy-saving, and passive energy-saving technologies on residential buildings and obtained significant information through the application of the Likert-type scale (Tastle et al., 2005) technique. This approach clarified the perception influence of construction suppliers and general public when implementing Smart Green Architecture into residential projects as well as clarified the importance of pro-environmental during Green Architecture planning.

## Literature Review

The insulation applying on building roofs of a green building architecture (Ozel and Pihtili, 2007) or the compounded materials on the walls and roofs have a direct impact on the comfortability of indoor rooms (Kumar et al., 2013). In addition, the roof of a green building has the most effective result in insulation (Silva et al., 2015; Bevilacqua et al., 2015). Moreover, double facades have natural ventilation effects (Silva et al., 2015; Blanco et al., 2014). Furthermore, comparing with single facades, double facades have empirical thermal comfort (Huckemann et al., 2010). Apart from the above mentioned materials, designs and techniques have a direct impact over green residential buildings. Other factors also include double-layer glass (Sun et al., 2016), Low emissivity glass (LOW-E glass), ventilation design (Belleri et al., 2014) and solar power systems (DeVault et al., 2014) etc. Solar power systems and ventilation designs in particular utilize the advantage of nature resources based on the geographic environment and are the design factors for a green building project.

The factor which forms proactive energy-saving and passive energy-saving technique of Smart Green architectures in Taiwan is classified into 14 categories. A Low Smart

Green Architecture in particular focuses on the structure first, then structure and facility. The four main building structures consist of insulated roof, exterior insulated wall, concrete floors, and roof eaves. The 6 sub-structures consists of sunroof, large number of windows, LOW-E glass, intensified shading effect by plantation, green roof, and ventilation design. There are 4 building facilities which consist of rainwater storage system, energy-saving light, solar power plate and low Volatile Organic Compound (VOCs) coating. In addition, there are 9 categories for high Smart Green Architectures which include timers for ventilation fan in the shower room, multi-split air conditioner, solar power system, programmable temperature control system, and photovoltaics sensing system. The above mentioned items are currently the most significant factors for the promotion of Smart Green Architectures in Taiwan.

The Ministry of Interior in Taiwan has carried out research on the topic of Smart Green Architecture since 1992 and in 2002 the Ministry of Interior has further promoted the concept of Smart residential space, and have started Smart Architecture Mark evaluation system to quantify the research. The application handbook of Smart Architecture Mark has been published in 2003 and it officially accepted the application of Smart Architecture Mark in 2004. In addition, in order to achieve the promotion and implementation of Smart Green Architectures for the smart emerging industry which carried out by the Ministry of Interior in Taiwan, the application of green Architecture and Smart equipment have been enhanced and expanded. This aims to meet the future lifestyle and environmental requirement of Smart Architectures and to achieve the promotion and development of the Smart Green Architecture industry. Four major promotional policies (total of 28 measures) were introduced and implemented between 2010 to 2015. The Smart Green Architecture promotion policy emphasizes on the environmental quality and ecological factors of residential areas. This consists of the architecture as the main carrier for Smart Green Architecture and implements Green Architecture design, high Smart technology, and the application of materials and products so as to provide health and safety, convenience and comfortability, the energy-saving and environmental friendly concept to the general public and proceed with the research of innovative technologies, products, systems and services. It is expected to establish production, lifestyle, and ecology to achieve high quality living environment and to simultaneously raise industrial competitiveness and grasp large innovative industrial business opportunities. To increase residential living environment. Moreover, it is expected to promote the development of technology industry.

### ***Information classification and comparison***

This study has selected 10 oversea Smart green residential buildings as a case study and has classified the findings in *Table 1* based on proactive energy-saving and passive energy-saving. The comparison of the design factors for oversea Smart green residential buildings is shown as follows.

From the above comparison table of design factors for oversea smart green residential buildings (*Table 1*), it indicated that the factors which affect the thermal insulation and shading are: insulated roof, insulated exterior wall, roof, and LOW-E glass. The table also indicates that the factors which affect the ventilation are: large number of window and the design of the ventilation system. The factors which affect energy-saving are: rainwater storage system, energy-saving lighting, solar power system, and programmable temperature control system. The factors which reduce the impact on health related issues is low VOCs coating.



**Table 1.** Comparison table of design factors for oversea Smart green residential buildings

Item	Passive energy-saving										Proactive energy saving												
	Primary structure			Secondary structure					Equipment		Equipment												
	Insulated roof ( Thermal insulation )	Insulated exterior wall ( Thermal insulation )	Concrete floor ( Thermal dissipation )	Roof ( Shading )	Sunroof ( Lighting )	Large number of window ( ventilation )	LOW-E Glass ( Thermal insulation )	Intensified planation for shading	Green roof ( shading )	Ventilation design ( Thermal dissipation & ventilation ball )	Rainwater storage system ( Water-savings )	Energy-saving light ( power-saving )	Solar power panel	Low VOC's coating	Ventilation timer for shower toom ( power-saving )	Temperature and humidity monitor	Geothermal heat pump	Adjustable boiler ( power-saving )	Mechanical ventilation system	Split air conditioner ( power-saving )	Solar power system ( power-saving )	Programmable temperature controller ( power-saving )	Photovoltaics sensing system
Benavieds Residence	√	√		√		√				√	√	√	√	√								√	
Black Residence		√	√			√	√			√		√	√	√		√							
Capitol Court Home	√	√		√	√	√				√			√	√			√	√				√	
District Home		√		√	√					√	√		√						√	√	√		
Madill	√	√		√	√	√	√			√			√			√						√	
BedZed	√	√						√	√	√			√		√						√		
Berliner Str42-48					√	√										√						√	
Ferrier	√	√		√	√	√	√			√	√		√								√	√	√
Bluff Dale	√	√		√	√								√								√	√	
Parker County	√	√		√	√	√				√	√		√								√	√	

In addition, there are five residential projects which were been certified by Smart Architecture Mark during 2009 to 2013. This study consolidated relevant information on Smart design technology for three residential projects. The consolidation consists of 4 items of door access management, 4 items of environmental monitoring control, 2 items of health management, 2 items of entertainment sharing with a total of 12 items for the design technology of smart residential projects. *Table 2* shows the consolidated items discussed above for those three projects:

**Table 2.** *Items of the smart building design technology for those three projects*

Category	Content
Door Access Management	<ol style="list-style-type: none"> <li>1. Handheld information technology device (i.e., cellphone), auto connected security door (electronic security)</li> <li>2. Access Recognition System (i.e., fingerprint, eyes)</li> <li>3. IP cloud home security system (monitoring home status at all time)</li> <li>4. Information and communication connected within the community via internet (monitoring community area status at all time)</li> </ol>
Environmental Monitoring System	<ol style="list-style-type: none"> <li>5. Smart LED lighting</li> <li>6. Set up temperature humanity sensing device</li> <li>7. Smart air-conditioner and smart power control system</li> <li>8. Hazardous gas detector (i.e., carbon monoxide, carbon dioxide)</li> </ol>
Health Management	<ol style="list-style-type: none"> <li>9. Body status measurement (data transmitted and saved to cellphone)</li> <li>10. Home health-care monitor (transmitting data direct to the health care center)</li> </ol>
Entertainment sharing	<ol style="list-style-type: none"> <li>11. Provide easy card function on a cellphone, and use it as a door access device and payment for bus fees</li> <li>12. Platform for entertainment media such as digital photo frame, desktop interaction device, and to provide family sharing, viewing for a better relationship.</li> </ol>

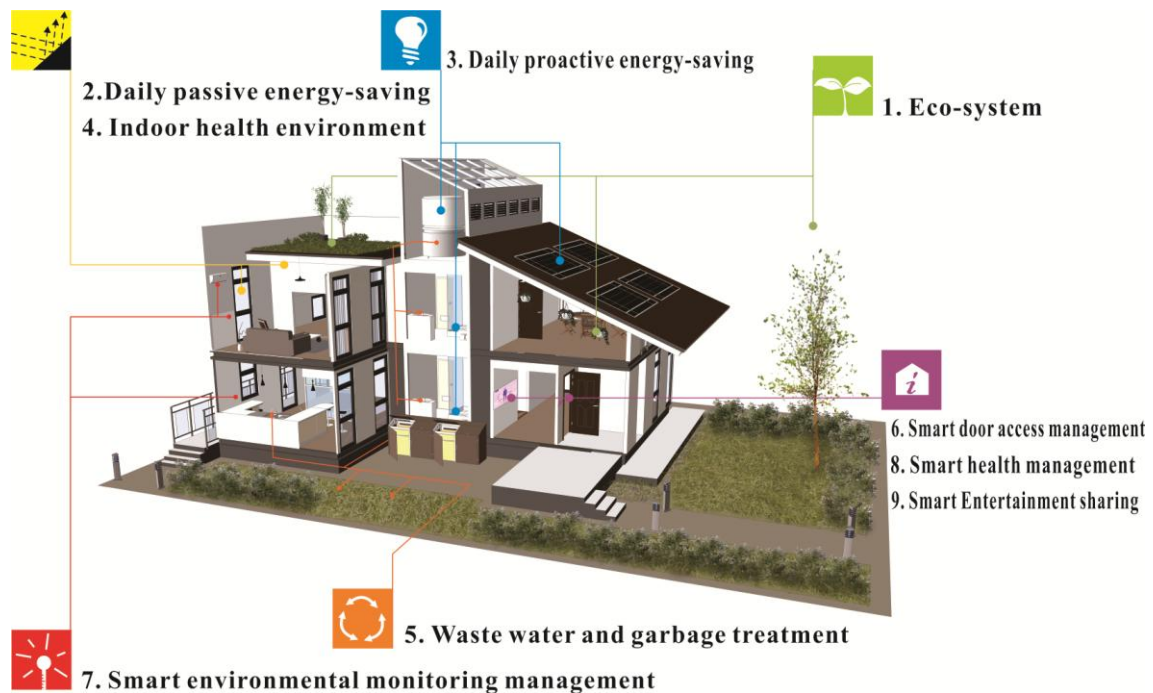
## Research method and questionnaire

### *Likert-type scale*

The Likert-type scale was established by Rensis Likert and is a measure of psychological reactions. It is commonly used in the form of questionnaire. This method is widely used in most of the research as the core measurement of psychological reactions. The advantage of applying the Likert scale is that when the interviewee answers the questions, it enables participants to be more specific to the level of acceptance (Weijters et al., 2016; William et al., 2005).

### Data preparation

This study has consolidated relevant literatures with regard to smart residential green buildings and categorized case studies from oversea, and the study carried out by the Ministry of Interior, Taiwan on the technology of green architecture and smart residential building as well as regulations on the exercise of autonomy of Kaohsiung green architecture as the reference when designing the questionnaire. Moreover, Likert-type scale can also be applied when designing the questions in order to enable participants to be more specific to the level of acceptance. In addition, in order to prevent an ineffective questionnaire data caused by technical terms used in the questionnaire and to increase the effectiveness of the questionnaire data, a diagram of smart residential green building has been illustrated in 3D format. Per *Figure 1*, all the technical terms were transformed into a diagram which would be easily understood by most participants.



*Figure 1.* 3D diagram of a smart residential green building

This study distributed 40 copies of questionnaire to practitioners, 73 copies to the general public and received 32 copies of effective questionnaire from practitioners and 54 copies of effective questionnaire from the general public.

### Investigation on the application of smart green building technology from practitioner

- (1) Gender proportion: 15 male participants (46%), 17 female participants (54%)
- (2) Age analysis: age 25-30: 3 participants (9%), age 31~35: 10 participants (31%), age 36~40: 12 participants (38%), age 41~45: 4 participants (13%), age 46~40: 2 participants (6%), age 50~55: 1 participant (3%), age 36~40 is the highest investigation group of this study.

- (3) Education qualification: high school or higher education: 1 participant (3%), undergraduate: 18 participants (56%) and postgraduate: 13 participants (41%).
- (4) Occupation: architecture: 15 participants (47%), construction : 4 participants (12%), others (relevant designers): 13 participants (41%)
- (5) For the questionnaires which have been returned, 32 participants have been in contact with construction development projects of congregate housing designs.

The technique applied for smart green building can be categorized into 9 major areas; these are residential environment eco-system, daily passive energy-saving, daily proactive energy-saving, healthy indoor environment, community waste water and garbage treatment, smart door security management, smart environmental monitor system, smart health management, and smart entertainment sharing. An investigation has been carried out based on these 9 major categories and 32 local architectures or property developer, and construction companies were involved to better understand the technique rating of residential design plans (with the primary focus on congregate housing). The popularity rating method is to prioritize those with highest score starting from point 9, 8, 7 and so on.

#### ***Investigation on the preference of Kaohsiung citizens with regard to the promotion of smart green building***

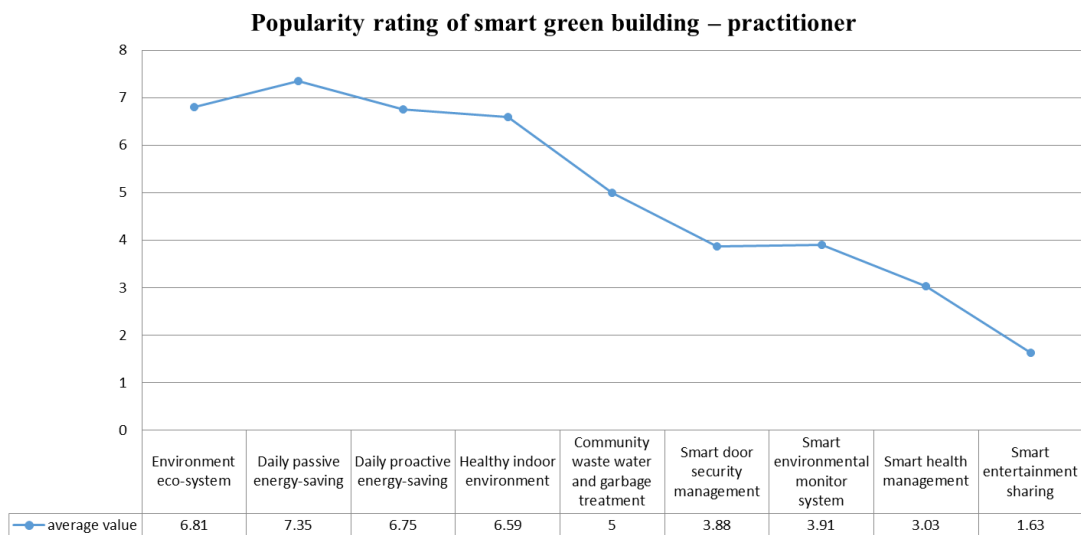
- (1) Gender proportion: 29 male participants (53.7%), 25 female participants (46.3%)
- (2) Age analysis: age 30~35: 9 participants (16.7%), age 36~40: 6 participants (11.1%), age 41~45: 10 participants (18.5%), age 46~40: 13 participants (24.1%), age 51~55: 11 participant (20.4%), age 56~60: 4 participants (7.4%), age 61~65: 1 participant (1.9%)
- (3) Education qualification: elementary/junior high school: 4 participants (7.4%), high school or higher education: 19 participant (35.2%), undergraduate: 21 participants (38.9%) postgraduate: 7% participants (13%), PHD: 3 participants (5.6%)
- (4) Income analysis: below \$20,000: 5 participant (9.3%), \$20,001~40,000: 32 participant (59.3%), \$40,001~\$60,000: 9 participant (16.7%), \$60,001~\$80,000: 5 participant (9.3%), \$80,001~\$100,000: 2 participant (3.7%) and exceed \$100,001: 1 participant (1.9%)
- (5) Occupation: public servant: 4 (7.4%), teacher: 4 (13.0%), agriculture: 1 (1.9%), labor: 14 (25.9%), commercial: 15 (27.8%), housewife: 2 (3.7%) and others: 11 (20.4%).

The techniques applied for smart green buildings can be categorized into 9 major areas; these are residential environment ecosystem, daily passive energy-saving, daily proactive energy-saving, healthy indoor environment, community waste water and garbage treatment, smart door security management, smart environmental monitor system, smart health management, and smart entertainment sharing. An investigation has been carried out based on these 9 major categories and has taken into the consideration of the preference and factors when considering house purchase. The investigation targeted at participants who are located in Kaohsiung and over the age of 30. Rating method is to priority those with highest score starting from point 9, 8, 7 and 1 being the last.

## Results and Discussion

### *Investigation on the application of smart green building technology from practitioners*

According to *Figure 2*, the analysis result of the questionnaire indicated that the community waste water and the garbage treatment have an average point of 5 which is in the middle. There are 4 items which are above the score of 5 and shall be regarded as the indices of green building techniques. Passive energy-saving has the highest score of 7.35. Residential environment ecosystem is in the second place with the score of 6.81. In the third place is daily proactive energy-saving and the fourth place is healthy indoor environment. There are 4 items which are below the score of 5 and shall be regarded as the indices of green building techniques. Smart entertainment sharing has the lowest score with 1.63, in the sixth place is smart environmental monitoring system with the score of 3.91, in the seventh place is smart door access management with the score of 3.88, in the eighth place is smart health management with the score of 3.03. From the above results, we can conclude that out of the 32 participants most of them take into consideration of green building (with the primary focus on congregate housing) more than smart building.

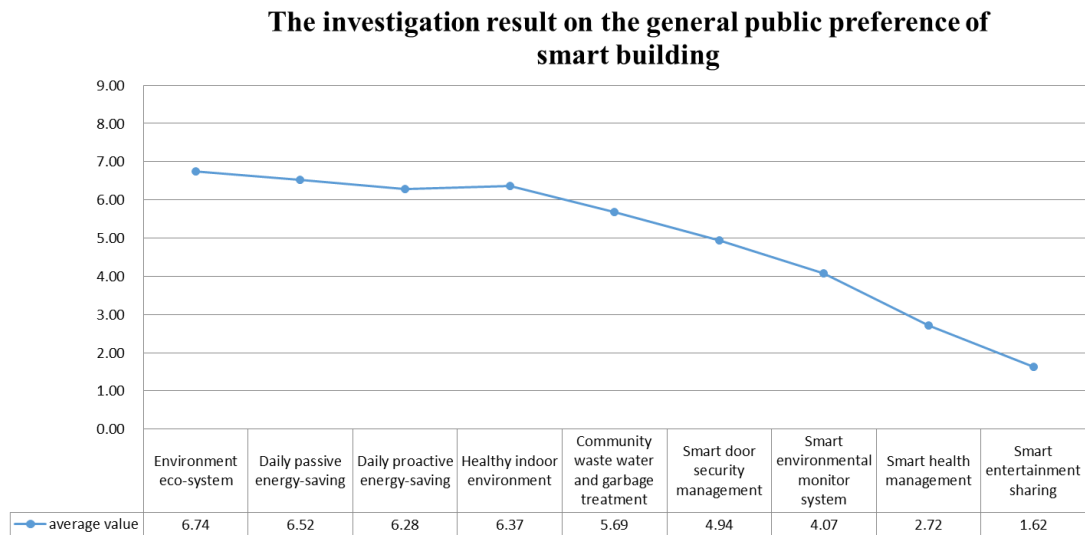


**Figure 2.** Popularity rating of smart green building – practitioner

The questionnaire pointed out one open-ended question to architecture practitioners. This question is ‘are there any recommendations which you would like to provide with regard to the smart green architecture projects which the government is attempting to promote?’ The result indicated that cost and subsidy are the two major feedbacks from the private sector. In addition, it is expected to define the market position of smart green architecture in Kaohsiung instead of over-priced smart architecture design. Practitioners have pointed out enhancing privacy, raising awareness to the general public, implementing social benefit policies, providing advices case by case, better use of nature environment of the foundation, considering building and facility separately as a part of the recommendation.

### ***Investigation on the preference of Kaohsiung citizens with regard to the promotion of smart green building***

According to *Figure 3*, the analysis result of the questionnaire indicated that smart door access management has an average point of 4.94 which is close to the middle of 5. There are 5 items which are above the score of 5. Ecological Residential environment has the highest score of 6.74; in the second place is daily passive energy-saving with the score of 6.52. In the third place is indoor health environment with the score of 6.37, fourth place is daily proactive energy-saving. The fifth place is community waste water and garbage treatment with the score of 5.69. There are 3 items which are below the score of 5. Smart entertainment sharing has the lowest score with 1.62, in the seventh place is smart environmental monitoring system with the score of 3.91, in the eighth place is smart health management with the score of 2.72. From the above statement we can conclude that a large majority of Kaohsiung citizens take into consideration of green buildings (more than just smart buildings).



**Figure 3.** Investigation results on the general public preference of smart buildings

The smart green building preference by different age bracket indicated that the age bracket between 51-65 takes residential environment ecosystem as an important factor and factors such as daily passive energy-saving, daily proactive energy saving, indoor health environment, and community waste water and garbage treatment also have a preference score above four. In general, most of the age brackets have a high acceptance level in green building technology. The acceptance level in smart building technologies is low. However, the result indicated that four smart technologies still has its own market, i.e., age bracket 56-60 takes smart health management as an important factor (5 points); age brackets 30-35 and 36-40 takes smart entertainment sharing as a high preference level (*Figure 4*).

According to *Figure 4*, this study took the score of level one (9 major categories) and the score of level two (38 technical methods) to derive *Figure 5*. As per *Figure 5* regardless of the construction consideration from practitioner nor the preference of traditional green building method of the general public, this study recommended Kaohsiung to promote smart green buildings in the order of residential environment

ecosystem, daily passive energy-saving, daily proactive energy saving, indoor health environment, and community waste water and garbage treatment. These are the five matured categories of low smart green building strategies.

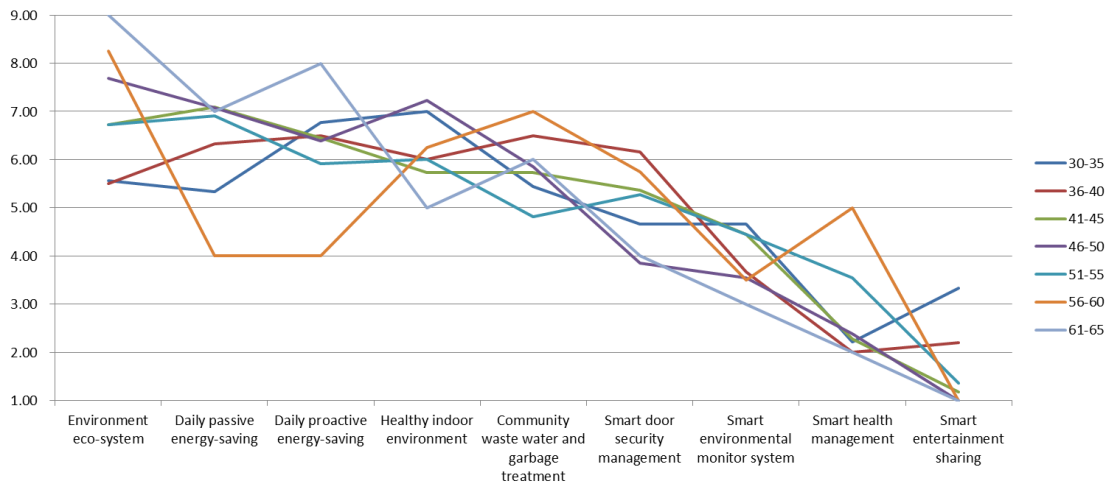


Figure 4. Smart green building preferences by different age brackets

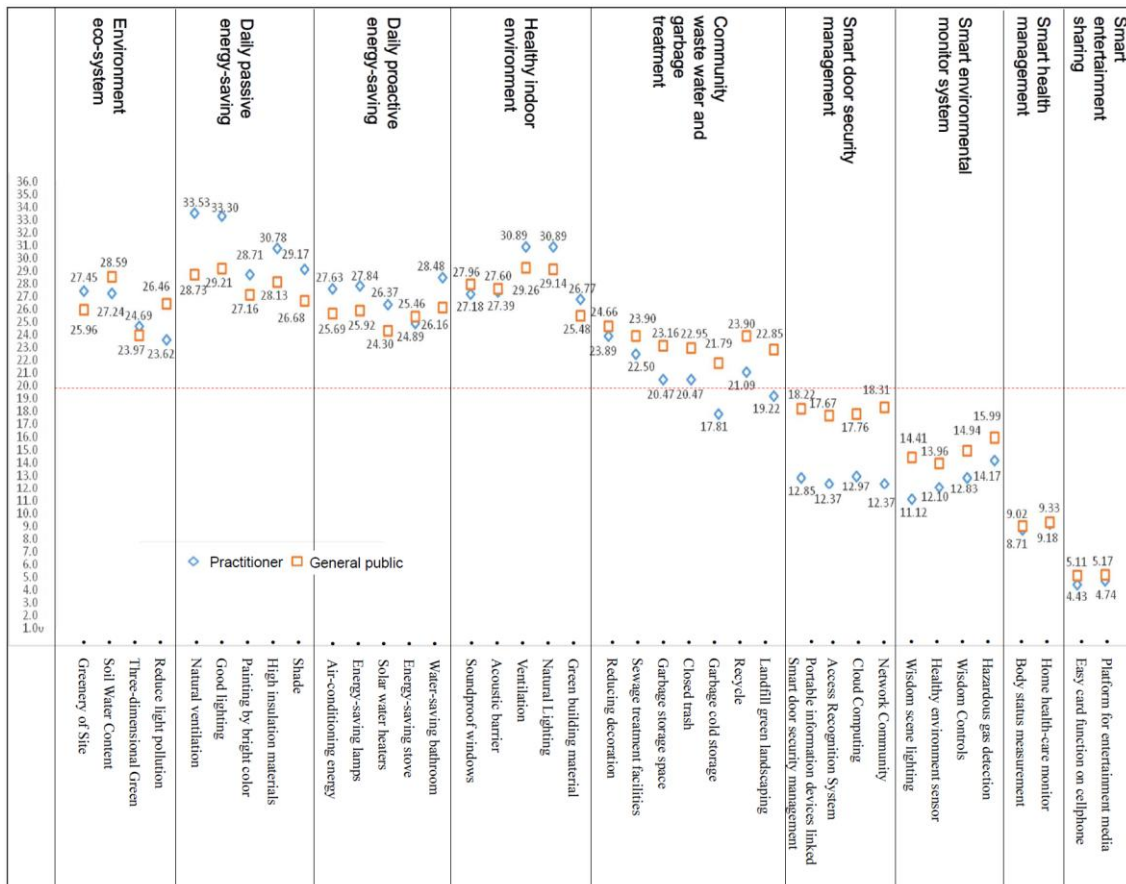


Figure 5. Statistical result of weighted scores from general public and practitioners

## Conclusion

This study has taken practitioner's construction factors and general public's preferences into consideration so as to derive the below conclusion and recommendation

### *From design point of view*

Cost and regulation are the major factors from the view of practitioners when considering construction. It is recommended to apply Kaohsiung green building regulations on the exercise of autonomy as the template to generate incentive policies or training programs.

The reason for the low score on high-tech smart design methods is due to the cost factor and the practicality factor. From the score it can be concluded that the future promotion of high-tech smart design technologies shall emphasize on functionality such as safety monitoring, elderly caring, etc. This would assist the promotion and implementation in the event that the general public accepts this recommendation.

In view of the practitioner with regard to smart building regulations, it is still recommended to review the project on a case-by-case basis.

Practitioners emphasized on exterior wall, structure, green, lighting, ventilation, regulation, etc. when planning the design. Therefore, they have disregarded interior design as it is not part of the job description. However, the promotion of green buildings is the combination of both interior and exterior designs, and the integration of resources in order to achieve the most effective result.

### *Preference of the general public*

The result of the questionnaire survey indicated that the top two significant factors when making purchase of a house are (proactive/passive) energy-saving and indoor health environment.

Despite of the fact that high-tech smart design method score is low, it is still above the point of 3 and this indicated Kaohsiung citizens do not reject the development of high-tech smart buildings. Therefore, cost and practicality factors are not significant when considering a house purchase.

The investigation on age brackets indicated that younger age bracket (30-40) has a higher acceptance level with regard to high-tech.

The environmental education of the implementation of smart green residential shall connect to the general public day-to-day living standard so as to enable the general public to be involved during the promotion stage, for instead, energy-saving, health related topics. Once the value has been created in the mind of the general public, it is more likely for the general public to participate more proactively in the concept of raising smart green residency.

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## KEY FACTORS IN THE MEDIA PROPAGATION EFFECT OF ECOTOURISM

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**Abstract.** With the constant progress of Internet and communication technology, various emerging technologies and market applications constructed on network environments are progressed to influence people's reading habits and information collection methods. After being satisfied the material life, the citizens present abundant economic ability and time on the leisure life and the participation in leisure and recreation activity in past years. Rural ecological environments and historical and cultural monuments are the major recreation activity for public tourism, attracting people who live in urban jungles visiting the countryside for landscape appreciation and local culture experience. Users of the official website of Fujian Tourism Bureau, as the research subjects, are surveyed through online questionnaire. Total 1000 copies of questionnaire are distributed and 683 valid copies are retrieved, with the retrieval rate 68%. According to the overall weight of evaluation indicators for the factors in the media propagation effect of ecotourism, the research results show top five indicators, among twelve ones, of customized services, development and network externality application, catering to the market taste and creativity, novelty and exploratory experience, and hardware development of devices. Suggestions, based on the research results, are proposed in this study, expecting to influence the ecological conservation issue on the public life through mass media as well as to promote ecotourism.

**Keywords:** *digital reading, consumer, delphi, industrial environment, technology*

### Background and motivation

With the changing technologies, the public can easily accept information and depend more on electronic media. Besides, people appear fewer concerns on public affairs so that more easily accessed information becomes the major source of information. Print news media are daily issued and largely published, while the public news reading habit has gradually changed from traditional paper-based media to electronic media which allows real-time browsing and combines various functions. In the world wide web (WWW) environment, electronic media websites, as a type of information-provided service industry, need to strive for users' clicks and satisfy user demands. Information searchers, after using electronic media websites, would compare the websites with personal expectation as the reference of satisfaction with electronic media websites.

After being satisfied the material life, people have abundant economic ability and time to stress on leisure life and participate in leisure and recreation activity. “Natural landscape appreciation activity” is the highest recreation activity when the public engage in tourism, followed by “culture experiencing activity”. To cope with above demands, rural ecological environments and historical and cultural monuments in many touring spots are utilized for attracting people who live in urban jungles to leave cities for landscape appreciation and local culture experience. Ecotourism is a type of tourism covering nature conservation and leisure development. Under the concept of ecotourism, the tourism resources, with careful planning and management, could be maintained for the sustainable tourism activity. In comparison with mass tourism, Wong (2011) regarded ecotourism as the activity containing the objectives of nature conservation and recreation development. Factors in the media propagation effect of ecotourism are therefore discussed in this study, expecting to have the public easily understand the correlation between ecology, biodiversity, and the life through the process of transferring and transforming difficult ecology and biodiversity theories so as to achieve the promotion and communication effect. Besides, it allows the public applying and shaping ecological conservation issues, influences the ecological conservation issue on the public life through mass media, and promotes ecotourism.

## **Literature review**

### ***Electronic media***

The source of Internet revolution was constantly decreasing costs for computer storage and network bandwidth (Ho, 2012). News and information, through the rapid news and information storing, revising, and delivering on the Internet, therefore are no longer restricted by time units, as for traditional newspaper, television, and broadcast, present both linear and non-linear reading models, and allow readers easily producing news with texts, photos, or audio/video by sharing them on social networking sites (Bian and Forsythe, 2012). The constant development of Internet, technology, and communication technology has the type and classification of online publishing become diversified and has publishing through the Internet become a trend. Especially, after the emergence of world wide web (WWW) in the 90s, applying browsers to collect information, different from the use of E-mail and Telnet in the past, has become a part of daily life of Internet users (Ju and Sirkin, 2010).

Strand (2010) mentioned that news media contained not only newspapers, but also print media, broadcast, and television as the providers of news and information. Whatever combined above characteristics of news media and was presented with digital methods could be regarded as electronic media (Hall, 2012). Electronic media are defined in this study as being collected and edited by specific units or organizations, utilizing world wide web (WWW) for updating daily news information with websites, and applying web pages to issue or actively deliver information to offer readers’ reading and browsing with reading methods different from traditional ones. Lee and Cho (2010) revealed different characteristics between electronic media and traditional newspapers, as electronic news provided multiple choices of reading methods for promoting readers’ initiative. Yang (2011) indicated that, comparing to fixed layouts of traditional newspapers on which news and information could not be moved, readers, in the

electronic news reading process, could select interested information for editing personal-style news reports through the Internet hyperlink to satisfy the distinct demands for news reports. In other words, electronic newspapers offer readers with larger freedom and initiative to choose news reports (Gervautz and Schmalstieg, 2012). Electronic media are the news media industry as well as the digital publishing industry. Marshall et al. (2011) mentioned that reading documents, network information, or articles through digital media, such as digital reading devices of computers or smartphones, were the digital reading activity. Electronic media present news and information on different media devices, with electronic form, for readers' reading.

### ***Digital reading***

Sun (2010) revealed that paper was the uniform reading device for reading behavior in the past, because there was no other object to replace it. Nevertheless, there were various types of equipment in the digital reading time suitable for readers' reading habits. Some people were used to reading with large-screen computers, while some other users would read through mobile phones or tablet computers (Zarella, 2011). In the era when paper was the media device, different publications, although issued with paper forms, showed different types. For example, books were issued with book form, while calligraphy, painting, and newspapers were issued with paper form. Although different types were created to cope with various reading and publishing characteristics, they were still paper-based devices (Green and Oort, 2013). Kao (2011) also considered that a digital-type reading interface was considered as digital reading no matter how the original source of content or a new presentation type was either the document scanned from paper to become an image or directly edited in a computer. Digital reading activity is changed by new types of media and devices, but the reading communication and interaction, such as listening, speaking, reading, and writing, are not changed. As a result, the reading model is further explained, aiming at the characteristics of digital reading (Jacucci et al., 2010), as (1)traditional publishing model being challenged, (2)changes of readers' reading models, (3)interactive experiences in reading, and (4)far-reaching reading activity.

Müller et al. (2012) pointed out the key factors of media combination, digital reading characteristics, and digital reading devices in readers' electronic media reading processes.

- (1) Media combination: According to research on electronic media, electronic media websites were presented with different multimedia combinations and website functions like texts, pictures, photos, sound, animation, or films (Lewis and Porter, 2010).
- (2) Digital reading characteristics: Stafford and Grimes (2012) argued, through the research report of use conditions of news websites from ARO online survey, that electronic media readers concerned mostly about the characteristics of news instantaneity, operating simplicity and speed, classification and structure, picture and text size, smoothness, and aesthetic.
- (3) Digital reading devices: Based on E-book survey in Taiwan area from Insight Xplorer in October, 2010, personal computers (PC), Note-book, tablet computers (Tablet PC), smartphones, and e-book readers were top 5 mostly used digital reading devices with Internet access capability (Tim, 2012).

### ***Key success factor***

Jeong et al. (2012) considered that Key Success Factor (KSF) supported or threatened the achievement of company goals and was even the primary factors in the existence of a company. Leidecker and Hinrichs and Carpendale (2011) indicated that KSF should cover three analytic levels of macro environment, industrial environment, and enterprise environment, where opportunities and threats were found out from the macro and industrial environment and the competitor dimension for strategy validation and environment analyses. The advantages and disadvantages of an enterprise were further evaluated to analyze the resources and evaluate the distribution of limited resources on KSF so as to plan successful dominant strategies. KSF therefore is defined in this study as the prior consideration in industry analyses and the most important control variable in management. Mantha (2011) mentioned that the search for key success factors in the industry could examine an enterprise's resources and analyze the immediate opportunities and threats of the industry so as to set differentiation strategies which could not be followed or imitated by business operation or competitors. KSF presents four characteristics. (1) It dynamically adjusts with the changes of market, time, region, corporate body, industry, or product life cycle and needs to clearly understand any changes in environments. (2) It presents prospection, considers the future development of industry, and focuses not only on short-term objectives but also medium- and long-term trend. (3) Managers should confirm KSFs in the industry as the reference for decision-making and concentrate the enterprise resources on the most important field to reduce resource misallocation and develop competitive advantages of the enterprise. (4) Capital, manpower, and time are limited resources of an enterprise that managers should effectively apply such resources to the key successful field of the enterprise.

Shin et al. (2011) pointed out the key success factors in television program makers, including 1.necessary factors of core technology, company positioning, courage to innovate, targeted object, leader style, frequent change, brand image, and entry timing and 2.adequate factors of channel expansion, product attribute, casting ability, integration of production and marketing, low cost, agency of major brokerage business, promotional activity, and foreign partners. Kim and Lee (2011) explained the key factors in the third generation (3G) of mobile telecommunications service market as following. 1. Internal effects of an enterprise contain powerful application services, stability, security and network management ability of telecommunication systems, mobile terminal equipment satisfying consumer demands, payment distribution between telecommunication system businesses and other businesses, offer of personalized and customized 3G services, service content aiming at enterprise users, and mobile terminal supply speed satisfying market demands. 2. External influence on an enterprise covers complete governmental regulations and restrictions, diversified synergy of telecommunication enterprises, and external application of networks. Stever (2011) regarded the key success factors in websites with audio/video contents as value content orientation, long-term and rich audio/video sources, dealing with channel conflict with sub-layout management, reduction of streaming costs, understanding users to enhance the payment willingness, digital right management, market expansion and customer basis, and effectively sticking users.

## **Research design and methodology**

### ***Delphi method***

In this study, AHP dimensions and criteria are established based on Delphi Method. Delphi Method, also named expert investigation, is a decision-making approach by separately sending problems to experts, through mails, for the opinions, organizing the comprehensive opinions, which are returned to experts with predicted problems for further opinions when the experts revise the original opinions according to comprehensive ones, and running the steps for several times to gradually acquire consistent prediction results.

According to the system program of Delphi Method, opinions are anonymously given. In other words, no discussion or lateral linkage appears between experts, but merely the relationship with the researchers. Through several runs of questionnaire survey, the prediction results are acquired with repeated inquiry, deduction, revision, and organization of consistent expert opinions. Such a method presents broad representativeness and is considered more reliable.

### ***Establishment of evaluation indicators***

The questionnaire in this study is sent to experts in various fields through emails. The first-time expert feedback is organized the factors in the media propagation effect of ecotourism, then the factors with similar properties are classified and sent back to the experts for further opinions. The method is proceeded for several times through emails. Finally, an expert conference is held to gather all experts to set the factors in the media propagation effect of ecotourism, including industrial environment dimension, technology dimension, content dimension, and consumer dimension. Such key factors as the AHP dimensions and the classification as the criterion are used for establishing the AHP questionnaire. The evaluation factors, revised through Delphi Method, in this study are shown as below.

- (1) Industrial environment dimension (local culture and living habits, excellent talents for industries, complete policy act)
- (2) Technology dimension (hardware development of devices, selection of system specifications, development and network externality application)
- (3) Content dimension (catering to the market taste and creativity, rich audio/video sources)
- (4) Consumer dimension (targeted group, novelty and exploratory experience, user-friendly operation of platform interface, customized services)

### ***Research subject***

Users of the official website of Fujian Tourism Bureau are collected through online questionnaire as the research samples in this study. A total of 1000 copies of questionnaire are distributed and 683 valid copies are retrieved, with the retrieval rate 68%. Fujian Tourism Bureau, the affiliated institution of the provincial government in charge of tourism, presents the major duties of coordinating provincial tourism development, making provincial tourism development policies, plans, and standard, developing provincial domestic tourism and inbound and outbound tourism market development strategies and the organization and practice, organizing provincial tourism

resource census, planning, development, and relative protection, undertaking the order of tourism markets, monitoring and managing the quality of service, protecting legal rights of tourism consumers and operators, promoting provincial tourism and international exchange and cooperation, and making, organizing, and practicing tourism talent planning.

### Data analysis result

After completing all hierarchic weights, indicators in different levels are distributed according to the relative importance to show the importance of indicators in the entire evaluation system, and the overall weight of factors in the media propagation effect of ecotourism is shown in *Table 1*.

**Table 1.** Overall weights of factors in Taiwanese catering businesses investing in China

Dimension	Hierarchy 2 weight	Hierarchy 2 sequence	Indicator	Overall weight	Overall sequence
Industrial environment dimension	0.140	4	Local culture and living habits	0.042	12
			Excellent talents for industries	0.064	9
			Complete policy act	0.052	11
Technology dimension	0.289	2	Hardware development of devices	0.087	5
			Selection of system specification	0.073	7
			Development and network externality application	0.126	2
Content dimension	0.267	3	Catering to the market taste and creativity	0.102	3
			Rich audio/video sources	0.071	8
Consumer dimension	0.304	1	Targeted group	0.082	6
			Novelty and exploratory experience	0.093	4
			User-friendly operation of platform interface	0.060	10
			Customized services	0.148	1



## Conclusion

According to the experimental analysis in this study, the following conclusions are summarized.

“Consumer dimension”, weighted 0.304, is the mostly emphasized dimension in Hierarchy 2, about 30.4% of overall weight, followed by “technology dimension” (weighted 0.289), “content dimension” (weighted 0.267), and “industrial environment dimension” (weighted 0.140). Such a result reveals that consumer dimension is the mostly emphasized factor in the media propagation effect of ecotourism.

The hierarchic weights of evaluation indicators in Hierarchy 3 are sequenced as below.

1. Evaluation indicators in industrial environment dimension are sequenced excellent talents for industries, complete policy act, and local culture and living habits.
2. Evaluation indicators in technology dimension are sequenced development and network externality application, hardware development of devices, and selection of system specification.
3. Evaluation indicators in content dimension are sequenced catering to the market taste and creativity and rich audio/video sources.
4. Evaluation indicators in consumer dimension are sequenced customized services, novelty and exploratory experience, targeted group, and user-friendly operation of platform interface.

By organizing the overall weight of evaluation indicators for the factors in the media propagation effect of ecotourism, customized services, development and network externality application, catering to the market taste and creativity, novelty and exploratory experience, and hardware development of devices, among 12 ones, are top 5 evaluation indicators.

## Suggestion

Based on the research conclusion, the following suggestions are proposed to provide definite guidance and direction for the media propagation effect of ecotourism.

1. The government should actively promote the production-broadcasting separation policy and assist ecotourism industry in establishing a common transmission platform. The frequency distribution should be licensed from the aspects of digital convergence and encouragement of ecotourism development, and the rules for ecotourism businesses operating media should be established. The management regulations for content channels should be rapidly clarified, and both social security and stimulation of ecotourism development should be taken into account for establishing the free-competition market mechanism.
2. In addition to the value, ecotourism businesses should actively integrate and coordinate the establishment of operating platforms, expand the cooperation in the industry, popularize the terminal equipment, and establish the business model. Ecotourism businesses should master the once-for-all steps for the mobile television service, including technology, user test, and business model integration. Successful media communication services should cover four stages of good infrastructure, well-placed hardware development of devices, mastery of catering to the market taste and creativity as well as novelty and rich exploratory contents, and offer of

customized personal services.

3. In addition to video content services, ecotourism businesses should create multiple and multiplex media innovation through data transmission technology, cut in from different value-added experiences, and create brand-new experience value for consumers. Moreover, ecotourism businesses should master key success factors, provide development and network externality application, and integrate unique services to establish the threshold which the competitors could hardly follow or imitate.

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

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(Received 12<sup>th</sup> Aug 2016; accepted 15<sup>th</sup> Nov 2016)

**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<sub>2</sub> 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<sub>2</sub> 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 2<sup>nd</sup> 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

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

Higher concentrations of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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

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<sub>2</sub> 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 Tānase, 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

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 ( $C.I. \leq 1$ ) and a consistency ratio of 0.1 or lower ( $C.R. \leq 0.1$ ) 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;

- (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

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

(3) Maximum priority vector :  $\lambda_{\max}$

$$\lambda_{\max} = (a_{ij}) \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} w'_1 \\ w'_2 \\ \vdots \\ w'_n \end{pmatrix}$$

$$\lambda_{\max} = (1/n) * (w'_1/w_1 + w'_2/w_2 + \dots + w'_n/w_n)$$

(2) Priority vector :  $w_i = \left( \prod_{j=1}^n a_{ij} \right)^{1/n} / \sum_{i=1}^n \left( \prod_{j=1}^n a_{ij} \right)^{1/n}$

(4) C.I.  $\leq 1$  ; C.R.  $\leq 0.1$

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

Figure 1. AHP formula and calculation steps

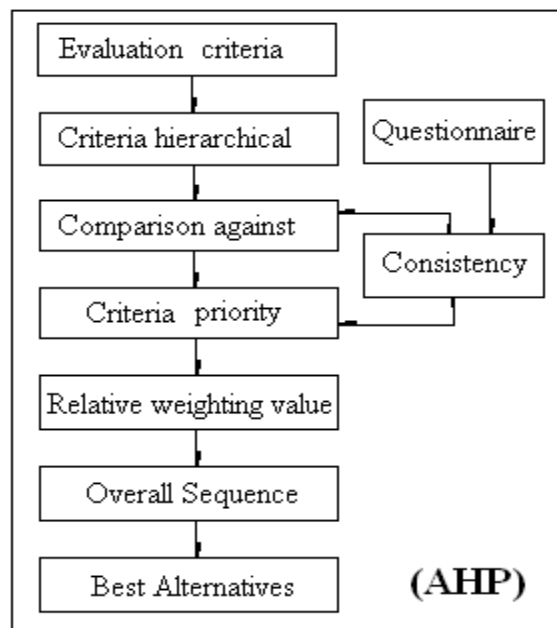


Figure 2. AHP implementation procedure

### 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;



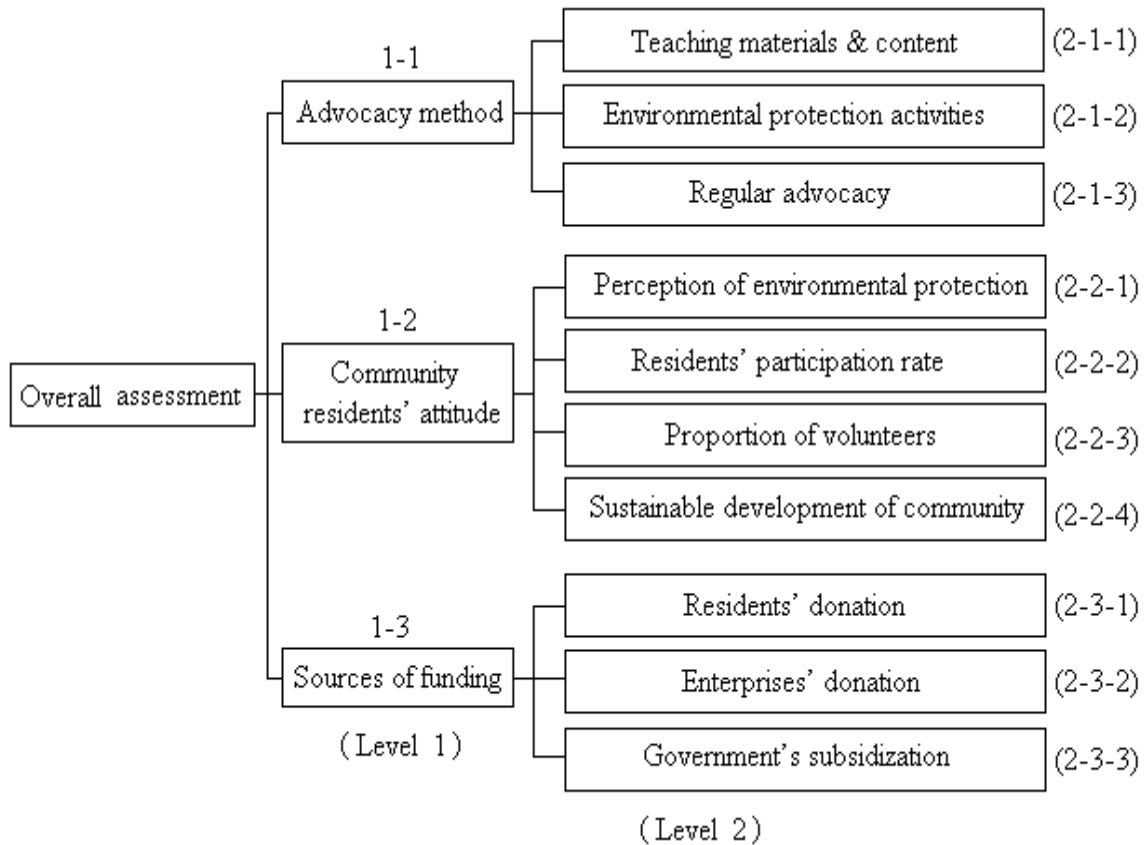
- (2) The AHP principles are used to establish the hierarchy of each evaluation factor;
- (3) The criteria extracted from the AHP questionnaire survey are ranked in a sequence of nine levels based on their relative importance;
- (4) A consistency test is conducted on the returned questionnaires and only those questionnaire data with a consistency index of one or lower ( $C.I. \leq 1$ ) and a consistency ratio of 0.1 or lower ( $C.R. \leq 0.1$ ) 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 ( $W_i$ ) 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*.



**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. $\leq 1$ C.R. $\leq 0.1$	Overall $W_i$	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 $W_i$					0.995	

### Discussion of the weight value ( $W_i$ ) 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.

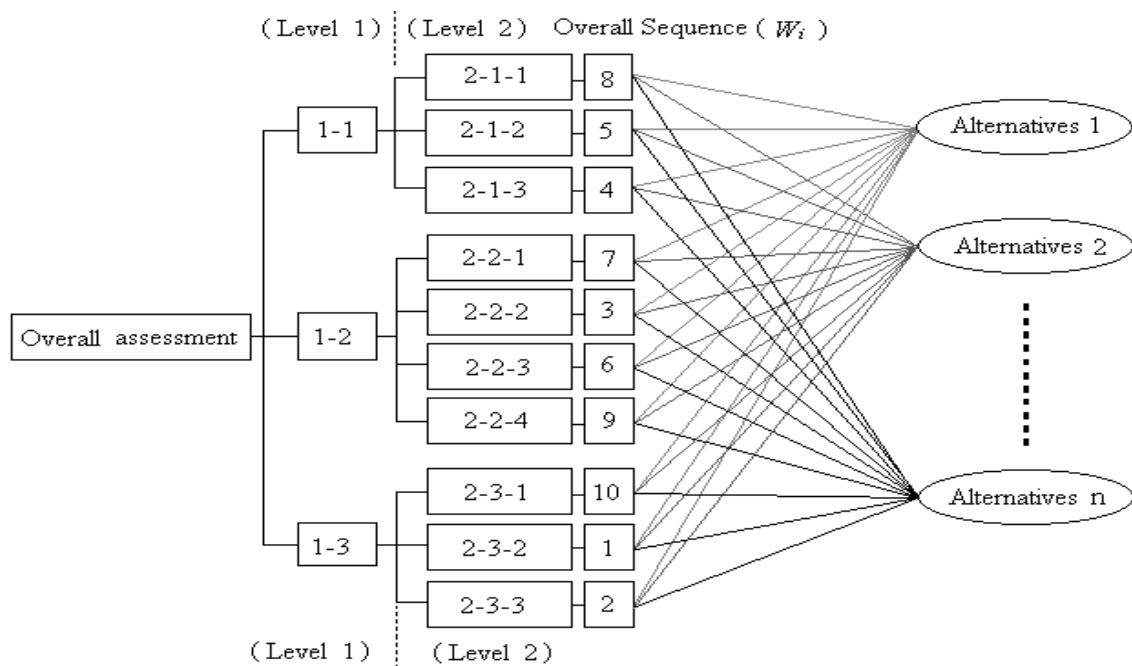
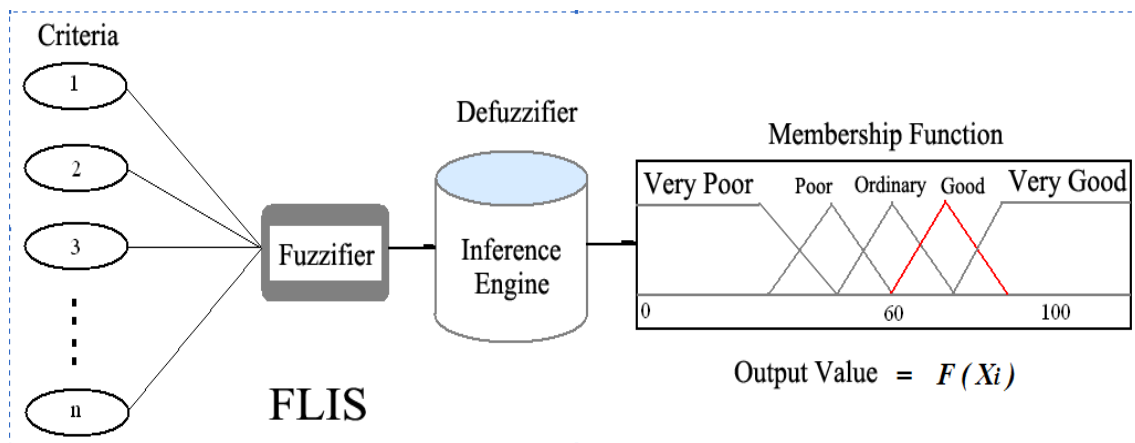


Figure 4. Overall AHP multi-criteria decision making model

### ***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 not 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.



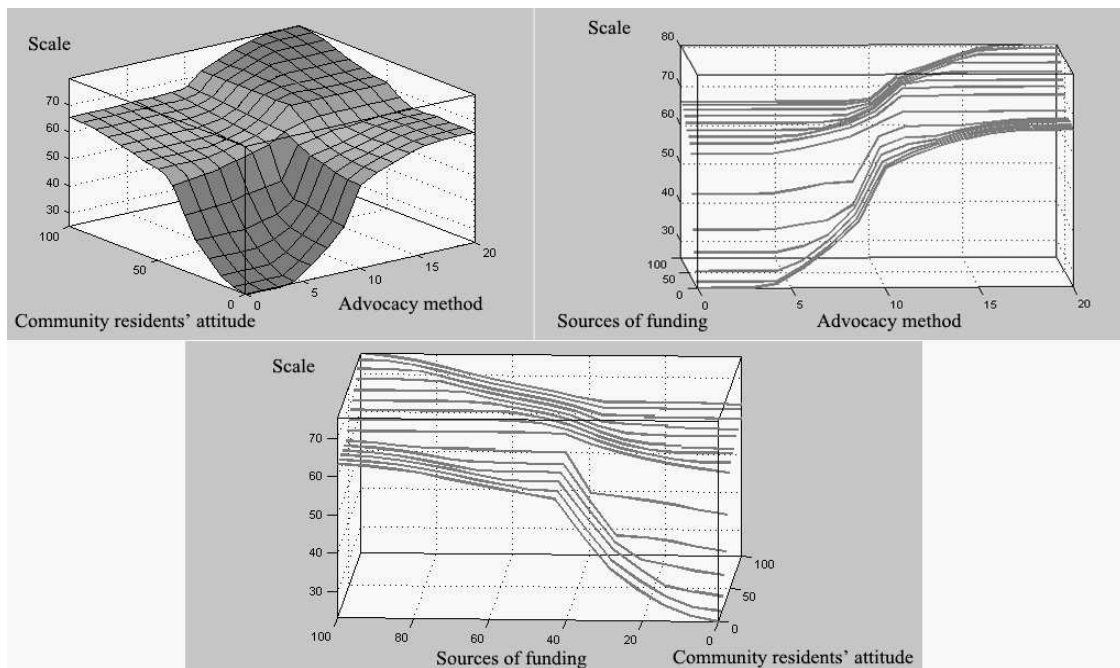
***Figure 5. Fuzzy logic inference system***

### ***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.

**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:

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

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

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		28.52		20.69		6.80
Community residents' attitude	0.394	91.4	36.01	66.3	26.12	21.8	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.

**Acknowledgements.** Much gratitude is owed to the Dahu Community in Kaohsiung City for funding this study (20151210 Green Home, Happy Community Research Project, an industry-academia collaboration research project) and providing relevant research assistance.

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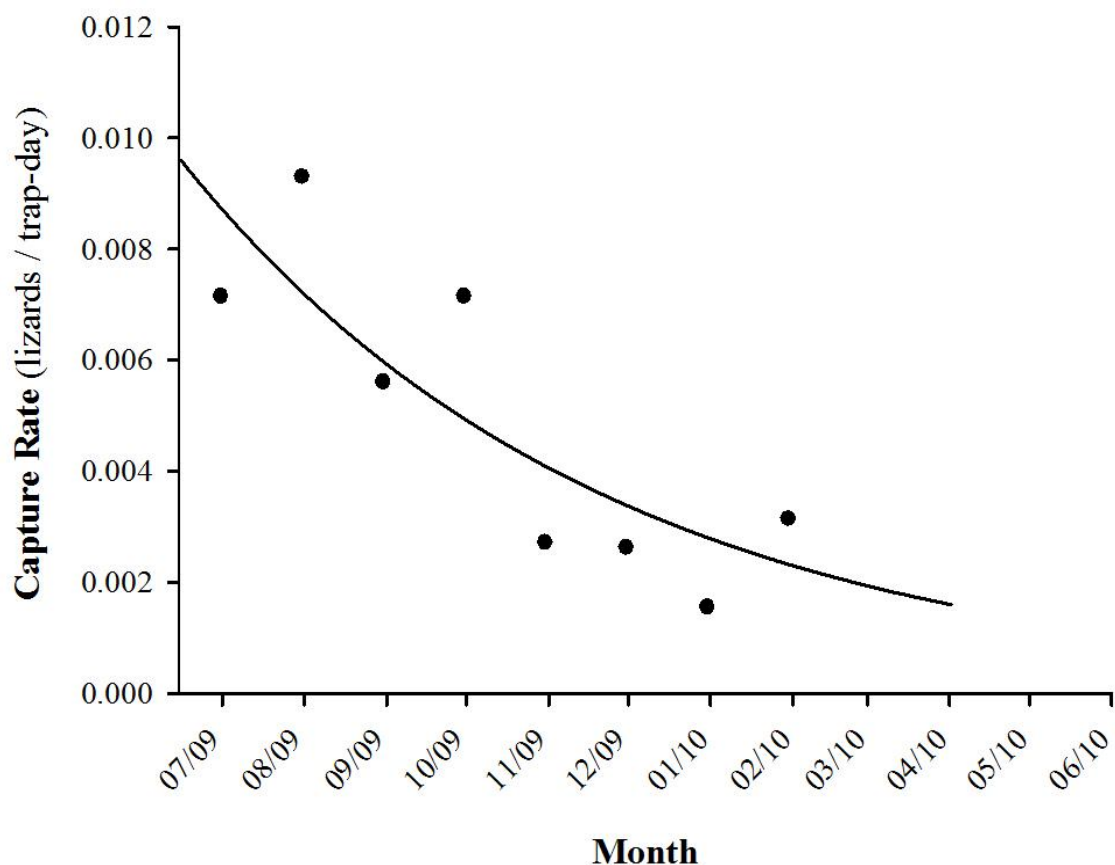


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# Applied Ecology and Environmental Research

International Scientific Journal

THEMATIC ISSUE ON ECOTURISM, SOCIETY AND BUILT  
ENVIRONMENT



VOLUME 15 \* NUMBER 2 \* 2017

<http://www.aloki.hu>  
ISSN 1589 1623 / ISSN 1785 0037  
DOI: <http://dx.doi.org/10.15666/aecer/1502>