Applying the Fuzzy Delphi Method to Analyze the Sustainable Neighborhood Unit Evaluation Factors

Kuei-Yang Wu
Department of Architecture
National United University
No. 1 Lien-Da, Kung-Ching Li, Miaoli 36003, Taiwan, ROC
Taiwan, ROC
kyw@nuu.edu.tw

Abstract: -The bottom-up concept in sustainable development has been rooted deeply in nations around the world yet regarding the implementation of neighborhood unit there is to date no effective modus operandi. Hence, building objective neighborhood unit evaluation criteria, which serve as the foundation of expanding municipal sustainable development and reference for sustainable neighborhood unit development decision making for local governments, is an important issue. When observing the relevant factors of exercising sustainable development, the factors were found to be interdependent. This research began with performing factor screening with Fuzzy Delphi Method and proceeded with Analytic Network Process (ANP) to calculate criteria weighting, and therefore constructed neighborhood unit evaluation model under the concept of sustainability.

Key-Words: - Sustainable Development; Neighborhood Unit; Fuzzy Delphi Method; Analytic Network Process

1 Introduction

In recent years, the application of fossil fuel and over-deforestation have caused the increase of greenhouse gas release, and the subsequent climate change that not merely leads to global warming, but also shift in weather patterns, sea-level rise, and eventually species extinction on earth [1-2] has become the issue of global concern. Hence all the nations actively hold various international conferences mainly to make nations around the world to put an emphasis on the problem of climate change and seek for solutions. The most noticeable of all are the United Nations Framework Convention on Climate Change (UNFCCC) the 15th Conference of Parties (COP15) and the 5th Conference of Parties (COP5) held in Copenhagen, Denmark, December, 2009, which covered the issues of curtailing release of carbon dioxide, underdeveloped countries in need of aid from developed countries in renewable energy and adaptation, mitigation policies for developed countries, and forest protection [3]. It can bee seen that sustainable development has grown into a momentous global issue.

Sustainable development in Taiwan mostly emphasized the construction of national or municipal level sustainability indexes, therefore no effective popularization was seen in local communities and neighborhood units, making the aforementioned index items and evaluation methods non-referable during neighborhood unit development [4]. For Taiwan neighborhood unit decision makers or residents, determining sustainability indexes and constructing evaluation methods have little help for performing neighborhood unit sustainable development. Mostly the indexes are based on the national or municipal level, which complicate the questions still more and block neighborhood units from effective implementation and making self-evaluation [5]. As a result, in exercising sustainable development, effective implementation and self-evaluation in due time for neighborhood unit decision makers or residents, and drafting policies in advance and planning integral objectives are essential before carrying out best improvement actions [6].

Concluding from the above, sustainable development must be progressed in a bottom-up manner, yet there have been no effective practices concerning implementation in neighborhood units. Thus construction of neighborhood unit sustainable development indexes has become a momentous issue in Taiwan today. This research shall first construct a preliminary index of sustainable development in Taiwan neighborhood units by defining connotations of neighborhood units through literature review, and data collection and analysis of local sustainability index construction in

ISBN: 978-1-61804-023-7

other countries. Then through Fuzzy Delphi Method (FDM) and expert interview the index factor screening is proceeded to make the neighborhood unit sustainable development index constructed in this research representative, and through Analytic Network Process (ANP) the expert questionnaire is performed to further reveal by quantitative methods the importance level and prioritization of neighborhood unit sustainable development indexes, so as to achieve and obtain the best neighborhood unit development criteria.

2 Sustainable Neighborhood Units

Under the standards of Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) enacted by U.S Green Building Council (USGBC), the sustainable neighborhood unit is primarily divided into two parts, one of which is the quantitative analysis performed of the neighborhood unit sustainable development under the impact of climate change, and the other one is the presently contained sustainable neighborhood unit potentiality designed according to the range of future conditions [8]. Takashi (2005) thinks that sustainable neighborhood units, which have self-adaptive ability and emphasize the interaction among people, can better preserve the local fine culture. Open neighborhood units are more helpful to themselves, and this fact is very important for local development since it not only improves the environment but also increases the communication and consultation among neighborhood units, and through that communication development can be further progressed to increase the possibility of sustainable development [7]. If sustainable development can proceed in neighborhood units, it can be expanded to development in communities or even cities. While developing, the quality of people, architectures, and environment should be first attended to, and human activities have to be limited appropriately to avoid damaging the ecological diversity, complexity, and functionality [9]. The construction of sustainable neighborhood units requires a mixed planning of neighborhood units and creates an overall design of local sustainable economic development, cultural tours, and local green plans. This kind of design plan has been undertaken as a practical guide in need of implementation, through which specialized knowledge is cultivated to solve more issues on sustainability [10].

3 Method

3.1 The Fuzzy Delphi Method

Many scholars introduce the fuzzy logic to Delphi method to resolve the defects of the traditional Delphi method, and with the principle of fuzzy logic, Delphi cumulative frequency distribution (Max-Min) algorithms and fuzzy integration algorithms were integrated and constructed; together these made the Fuzzy Delphi Method [11].

This research applies the Fuzzy Delphi Method to replace the traditional Delphi Method, and builds triangular fuzzy function according to average generalized model.

3.2 Analytic Network Process

The Analytic Network Process was bought by Saaty in 1996, which was presented in network type and generated from past Analytic Hierarchy Process (AHP) [12]. The emersion of ANP was in response to the actual context that many decision making problems can not be presented in AHP hierarchy structure since the indexes from differing levels have interdependent relations rather than linear relationship in factual situation.

ANP-modeled structures rather than AHP hierarchy structures resemble the network more. The process for Analytic Network Process matrix construction is to compare the criteria in pairs, and inquire the experts and scholars to pick the more important one of the paired criteria on a pairwise basis, rating them on the ratio scale from 1~9 [12-13]. For every ratio scale within the matrix there is the corresponding relationship of one within-cluster element affecting the other within-cluster elements (outer dependence.), or the impact imposed on elements within its own cluster (interdependency). Not all elements would affect other elements. Finally all cluster elements are listed in the corresponding position in the matrix, forming a complete synthetic matrix, which is the supermatrix.

4 Conclusion

4.1 Evaluation criteria for sustainable development neighborhood unit

The purpose of this research is to develop the Taiwan neighborhood unit sustainable development evaluation model. First of all 17 Taiwan neighborhood unit sustainable development importance indexes are sorted from relevant references [14-30] and expert interview, and are presented in table 1.

ISBN: 978-1-61804-023-7

Later 17 impact criteria are screened with the FDM to sort the exact evaluation criteria. The sampling population of Fuzzy Delphi questionnaires in this research contains opinions from 14 experts, with practical backgrounds of being community leaders, government sectors, architecture design, and scholars, etc., and thus common comments and perspectives are integrated to further select 16 exact neighborhood unit sustainable development impact criteria, which serves as evaluation criteria for constructing future evaluation model as a whole. Details are listed in table 2.

4.2 Constructing the evaluation model

This research is based on the 16 exact factors selected with the FDM according to the aforementioned four dimensions. In addition, for the control of characteristics of the empirical neighborhood units and their plan development and innovation, this research combines different domains such as the academic domain, public sectors, architecture design, community leaders, etc., and performs cluster analysis by 10 experts with years of practical experience and researches to construct the evaluation structure model as a whole, as listed in figure 1.

This research next with the Excel software calculates the EV values of all the aforementioned empirical matrices and places them according to the relevant position in the corresponding cell to build the preliminary supermatrix. Since the supermatrix does not fit the basic requirement of random sum as 1, to be objective, each item is given the same weighting (0.5) to make a weighted supermatrix. To get the global convergence value, the weighted supermatrix is made with Excel to multiply itself by 18 times to get the limit value and resulting in the limit supermatrix, in which all evaluation criteria (C_1~C_{16}) are expressly presented with their corresponding global convergence value in objective level (G), eventually obtaining the stable precedential weighted value.

From the weighted ranking in table 3, four segmented groups are designated: (1) Residents' consciousness coherence (C_2), safety (C_{15}), resource recycling and reusing (C_{10}), development of eco-idea lands (C_{11}). The differences among the weighted values of the four items are rather small (0.0856~0.1287), and on the front of all criteria items, priority items of neighborhood unit sustainable development are presented. (2) Environmental pollution control (C_9), voluntary participation in public matters (C_4), neighborhood unit organization construction (C_1), neighborhood unit interaction (C_3); this group presents mutual awareness and identity in need of being reinforced during neighborhood unit sustainable development, thus elevating participation of residents. (3) Green transportation (C_{12}), application of natural lighting, ventilation (C_6), habitability (C_{13}), green buildings (C_8); this group reflects the energy-saving perspective in need of being reinforced in local sustainable development, avoiding environmental pollution and energy consumption from buildings or traffic tools. (4) Completeness of public facilities (C_{16}), architecture arrangements (C_7), using renewable energy (C_5), accessibility (C_{14}); public facilities should enhance its local accessibility to prevent over-dependency on traffic tools and should strengthen the architectural design and use of regenerated energy.

From the above results of weighted analysis, neighborhood units have to first strength the resident interaction concept before exercising sustainable development. Residents' consciousness coherence is the most important (weighted value: 0.1287, weighted ranking:1); second, concerning environmental maintenance principles, resource recycling and reusing (weighted value: 0.0865, weighted ranking:3) and development of eco-idea lands (weighted value: 0.0856, weighted ranking: 4) should be reinforced to enhance residential emphasis and maintenance of environment to retain a friendly living environment for residents; third, in contents of substantial needs, safety (weighted value: 0.0918, weighted ranking: 2) is the most crucial entry, which means increasing safety of residential living environment to avoid excess pressure in the living of residents; last, in the dimension of viewpoints of energy conservation building design, concerning application of natural lighting and ventilation (weighted value: 0.0571, weighted ranking: 10) and green buildings (weighted value: 0.0389, weighted ranking: 12) reinforcement, the ventilation and lighting of buildings as well as green architecture can lower the dependence for indoor electric appliances, and in this way can reduce energy consumption to further achieve sustainable living standards.

5 Conclusion

This research integrates the FDM and ANP, combined with expert group decision making and interviewing to proceed with the construction of neighborhood unit sustainable development criteria, and based on the screening of the criteria and constructing of the evaluation model, it leads to the following results.

ISBN: 978-1-61804-023-7

First of all, through complete literature analysis and expert interview, four dimensions - residents interaction concept, energy-saving building perspective, environmental maintenance principle, and actual needs, are sorted, and the construction of all criteria is performed within each dimension. The dimension and the criteria would be the basic evaluation structure. Afterwards, this research through FDM integrates the quantitative numerical values of expert group objective review to proceed with criteria factors sorting to select important ones. The results screen the 17 possible impact factors in four dimensions into 16 evaluation principles, which according to expert importance consensus(G^i) prioritization are from high to low listed as safety, habitability, residents' consciousness coherence, environmental pollution control, application of natural lighting and ventilation, resource recycling and reusing, completeness of public facilities, voluntary participation in public matters, green buildings, development of eco-idea lands, architecture arrangements, neighborhood unit organization construction, availability, using renewable energy, green transportation and neighborhood unit interaction. These four major dimensions and 16 evaluation principles can be referred to as basis for sustainable development in neighborhood units. In addition, with the prioritization of expert consensus importance level, the precedential items to consider can be construed to serve as basis for future planning design and integral decision making.

In addition, after the FDM screening, this research also applies the core characteristic of ANP processing interdependent relationship, and expert review of possible results, and reflects the consideration and response of actual problems; it's conclusion highlights the mutual affecting relationship among evaluation criteria and aspects (O_1~O_4: C_1~C_{16}). Through the computing of supermatrix it expressly presents the mutual affecting or importance level among each evaluation criteria in numerical type; it factually reflects genuine needs for sustainable neighborhood unit development, with people, buildings, environment, and actual needs as basic aspects taken into consideration, and furthermore enhancing the construct of sensory image.

References:

[1] Houghton, J. and J. Lakeman (1996). Climate change 1995: The science of climate change: contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press Cambridge.

[2] Hansen, J., M. Sato, et al. (1998). "Climate forcings in the industrial era." Proceedings of the National Academy of Sciences of the United States of America 95(22): 12753.

[3] Green Peace. (2009), http://www.greenpeace.org/international/.

[4] Tsai, T.I., 2009. Reflection on strategies of sustainable environmental development after the 88 Taiwan flood. Economic Outlook on Environmental Protection, pp.43-50.

[5] Wu, K.Y. and Huang,H.D. (2009). Local environmental quality evaluation system based on fuzzy analytical hierarchical process. WSEAS Transactions on Systems 8(8): 988-1010.

[6] Wu, K.Y., Wey, W. M. Lin, W. Z.(2006). Using fuzzy analytic hierarchy process evaluates sustainablecommunity management in Miaoli city of Taiwan. WSEAS Transactions on environment and development 2(6): 792-799.

[7] Barton, H. (2000), Sustainable communities: the potential for eco- neighbourhoods , Earthscan/James.

[8] USGBC. (2005). LEED-ND: LEED for Neighborhood Development Rating System Preliminary Draft September 6, 2005, U.S. Green Building Council, Washington, D.C.

[9] Antrop M. (2006). Sustainable landscapes: contradiction, fiction or utopia? Landscape and Urban Planning 75(3-4):187-97.

[10] Jacob Wagner, Michael Frisch, and Billy Fields (2008). Building Local Capacity: Planning for Local Culture and Neighborhood Recovery in New Orleans. A Journal of Policy Development and Research:10(3):39-56.

[11] Ishikawa, A., M. Amagasa(1993). The Max-Min Delphi method and fuzzy Delphi method via fuzzy integration, Fuzzy Sets and Systems 55(3): 241-253.

[12] Saaty, T. L. (1996). The analytic network process. RWS Publications.

[13] Saaty, T. L., Takizawa, M. (1986). Dependence and independence: from linear hierarchies to nonlinear networks. European Journal of Operational Research.

[14] Baldwin, S., (1993). The Myth of Community Care. London: Chapman and Hall.

[15] Cohen, D., Inagami, S., & Finch, B. (2008). The built environment and collective efficacy. Health & Place, 14, 198e208.

[16] Semenza, J. C., & Krishnasamy, P. V. (2007). Design of a health-promoting neighborhood

intervention. Health Promotion Practice, 8, 243-256.
[17] Javid, D. (2007). LEED-ND is coming: are you ready? How to implement green planning and design principles now. APA California Planner, March-April, 13-16.
[18] Kamphius, C., van Lenthe, F., Giskes, K., Brug, J., & Mackenbach, J. P. (2007). Perceived environmental determinants of physical activity and fruit and vegetable consumption among high and low socioeconomic groups in the Netherlands. Health & Place, 13, 493-503.
[19] Cattell, V., Dines, N., Gesler,W., & Curtis, S. (2008). Mahdi Akhtarkavan, Amir Alikhani, Javad Ghiasvand, Hamid, Akhtarkavan.(2008). Assessing Sustainable Adaptive Re use of Historical Buildings. WSEAS International Conference on Cultural Heritage and Tourism (CUHT'08)95-100.
[20] Health & Place, 14(3), 544-561.
[21] Cohen, D., Finch, B., Bower, A., & Sastry, N. (2006). Collective efficacy and obesity: the pote4RU3UVntial influence of social factors on health. Social Science & Medicine, 62, 769-778.
[22] Sarason, S. (1977). The psychological sense of community. Jossey-Bass San Francisco.
[23] Chavis, D. and A. Wandersman (1990). Sense of community in the urban environment: A catalyst for participation and community development. American Journal of Community Psychology 18(1): 55-81.
[24] Molinari, C.(1998). The relationship of community quality to the health of women and men, Social Science & Medicine 47(8): 1113-1120.
[25] Yueh-Hsia Chiu, Li-Sheng Chen, Ming-Neng Shiu, Ting-Ting Wang, Hsu-Sung Kuo, Shiao-Chi Wu, Der-Ming Liou, and Hsiu-Hsi Chen (2003), Health Information System for Community-Based Multiple Screening, American Medical Informatics Association.
[26] Bull, S. (2002). Renewable energy today and tomorrow, Proceedings of the IEEE 89(8): 1216-1226.
[27] Robert Gross, Matthew Leach and Ausilio Bauen (2003). Progress in renewable energy. Environment International 29(1): 105-122.
[28] Sawin, J. (2004). Mainstreaming renewable energy in the 21st century. Worldwatch Inst.
[29] Twidell, J. and A. Weir (2006). Renewable energy resources, Spon Pr.
[30] Y. Yamaguchi, Y. Shimoda, M. Mizuno, (2007). Transition to a sustainable urban energy system from a long-term perspective: Case study in a Japanese business district, Energy and Buildings 39:1–12.

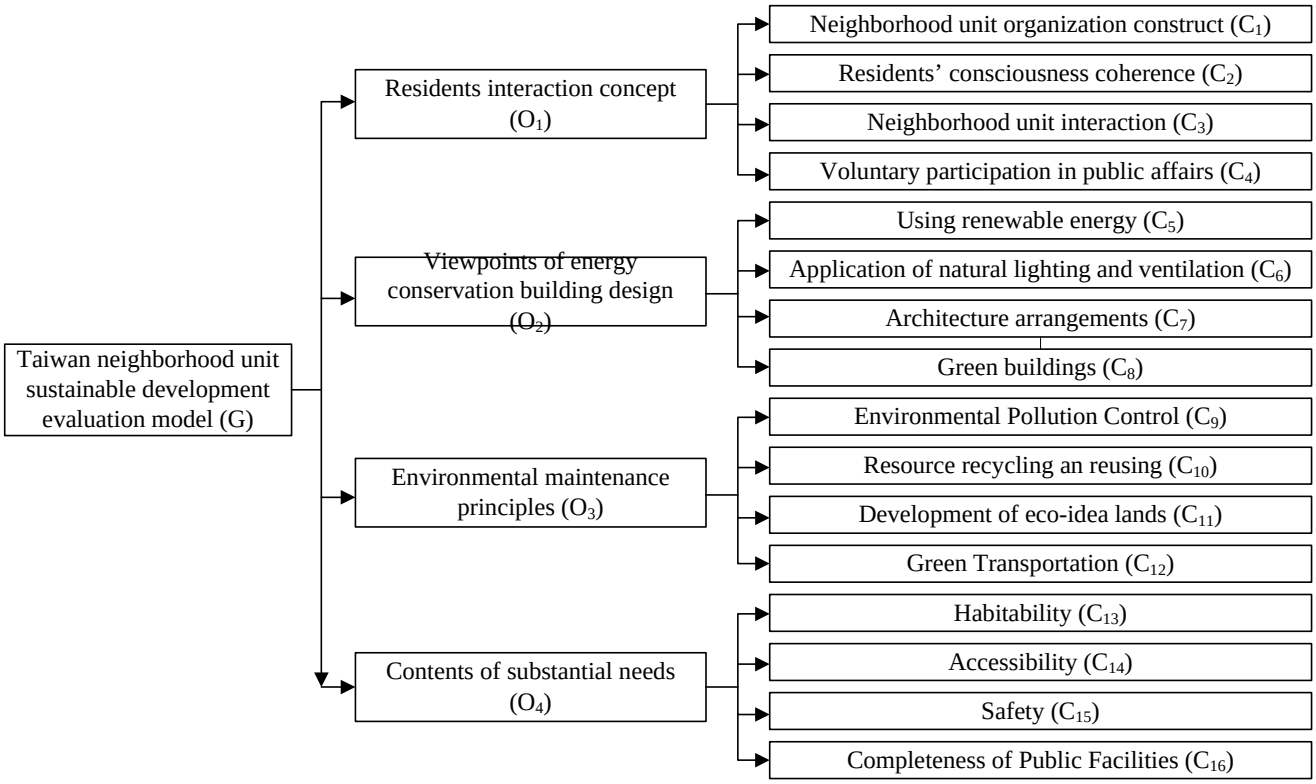

Figure 1. The evaluation structure model as a whole

Table 1. Dimensions aspects and possible impact factors

Objectives	Dimensions	Possible impact criteria
Taiwan neighborhood unit sustainable development evaluation model	Residents interaction concept	Neighborhood unit organization construct
		Residents' consciousness coherence
		Neighborhood unit interaction
		Voluntary participation in public affairs
	Viewpoints of energy conservation building design	Using renewable energy
		Application of natural lighting and ventilation
		Architecture arrangements
		Green buildings
		Application of ecological building materials
	Environmental maintenance principles	Environmental Pollution Control
		Resource recycling an reusing
		Development of eco-idea lands
		Green Transportation
	Contents of substantial needs	Habitability
		Accessibility
		Safety
		Completeness of Public Facilities

Table 2. Possible impact factors screening table

Dimensions / Possible impact criteria	Minimum		Max		Best value		Geometric mean			Z^i	G^i
	Min	Max	Min	Max	Min	Max	Min	Max	Best		
Residents interaction concept											
Neighborhood unit organization construct	4	7	7	9	6	8	5.719	7.897	6.817	2.179	7.046
Residents' consciousness coherence	5	8	8	10	7	9	6.794	9.189	8.108	2.396	8.443
Neighborhood unit interaction	3	8	6	10	5	9	5.295	7.730	6.648	0.435	6.519
Voluntary participation in public affairs	3	8	6	10	5	9	6.052	8.547	7.299	0.495	7.743
Viewpoints of energy conservation building design											
Using renewable energy	1	8	2	10	1	9	5.152	7.429	6.189	-3.723	6.559
Application of natural lighting and ventilation	4	8	6	10	5	9	6.811	8.976	7.895	0.165	8.398
Architecture arrangements	5	8	7	10	6	9	6.211	8.362	7.291	1.151	7.125
Green buildings	4	8	7	10	6	9	6.261	8.442	7.371	1.180	7.552
Application of ecological building materials	1	8	3	10	1	9	4.965	7.408	5.971	-2.557	6.443
Environmental maintenance principles											
Environmental Pollution Control	3	8	6	10	5	9	6.632	8.927	7.916	0.294	8.404
Resource recycling an reusing	5	8	8	10	6	9	6.599	9.028	7.859	2.428	8.110
Development of eco-idea lands	5	8	7	10	6	9	6.321	8.498	7.417	1.177	7.340
Green Transportation	3	8	5	10	4	9	5.504	7.564	6.539	-0.940	6.548
Contents of substantial needs											
Habitability	5	8	8	10	7	9	6.780	9.197	8.040	2.417	8.446
Accessibility	4	7	7	10	6	8	5.858	8.170	7.103	2.312	7.022
Safety	4	10	7	10	6	10	7.022	9.102	8.089	-0.920	8.625
Completeness of Public Facilities	5	8	7	10	6	9	6.560	8.791	7.717	1.231	7.816
16 variables were chosen (G^i are higher than the threshold (S)6.5)											

Table 3. Weighted value and ranking of relevant criteria

Criteria	Weights	Sorts of weights
Residents' consciousness coherence (C_2)	0.1287	1
Safety (C_{15})	0.0918	2
Resource recycling an reusing (C_{10})	0.0865	3
Development of eco-idea lands (C_{11})	0.0856	4
Environmental Pollution Control (C_9)	0.0792	5
Voluntary participation in public affairs (C_4)	0.0731	6
Neighborhood unit organization construct (C_1)	0.0671	7
Neighborhood unit interaction (C_3)	0.0631	8
Green Transportation (C_{12})	0.0573	9
Application of natural lighting and ventilation (C_6)	0.0571	10
Habitability (C_{13})	0.0552	11
Green buildings (C_8)	0.0389	12
Completeness of Public Facilities (C_{16})	0.0343	13
Architecture arrangements (C_7)	0.0323	14
Using renewable energy (C_5)	0.0249	15
Accessibility (C_{14})	0.0248	16

ISBN: 978-1-61804-023-7