行政院國家科學委員會專題研究計畫 成果報告

應用模糊延伸性之AHP法於綠建築社會性評價指標建立之探討

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行政院國家科學委員會補助專題研究計畫 ■ 成果報告
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應用模糊延伸性之 AHP 法
於綠建築社會性評價指標建立之探討

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中　華　民　國　九十八　年　九　月　八　日

行政院國家科學委員會專題研究計畫成果報告(精簡版)

應用模糊延伸性之 AHP 法於綠建築社會性評價指標建立之探討

Exploration to establish the social evaluation indicators for green building using fuzzy extended AHP-based approach.

中文摘要：
為有效引導集居環境永續發展、提升整體居住品質，評估指標建立為落實地區行動概念之關鍵基礎。台灣居住環境正漸次地朝向都市化、高層化之集合住宅社區發展；然而，所賴以依循之綠建築評估指標系統（EEWH）卻於制訂初時，未納入可反應高密度集居化特性之相關社會性因素！本研究係以使用者之居住態度、需求、品質與互動為出發，考量於自身特性並參酌國外施行體系，先行彙整出相關可能影響因子。接著，藉由地區調查採因素分析法（Factor Analysis Method）釐清使用者之實際需求與特質，萃取出具地區特色之社會性互動的主要成分，以作為強化既有指標系統之基礎。爾後，考量該主要成分於轉化為評價指標時，其本質係偏屬於主觀感知與質化不確定性之模糊多屬性決策分析（FMADA）問題，特援引結合模糊理論與分析階層程序法之模糊延伸性分析階層程序法（Fuzzy Extent Analytic Hierarchy Process Method），先行建構出階層式評估架構、進而藉模糊成對比較轉換成客觀明確之量化的權重值，以具體反映出各指標的重要性程度；最後，導入實際案例予以驗證。實證結果可明確呈現案例於社會性指標之優先排序，並彰顯出未來調整改善之具體方向。研究成果除可強化現行 EEWH 系統的完整性、有效提升整體集居環境品質外，還能作為未來規劃設計時之確切導引、以及提供相關政策研擬與推動時之參考依據。
關鍵詞：綠建築社會性指標、集合住宅社區、因素分析、模糊延伸性分析階層程序法

Abstract：
For guiding sustainable development of collective dwelling environment and improving residential quality effectively, the establishment of assessment indicator system is a critical groundwork for implementing the concept of "Acting Locally". In Taiwan, the residential environment is developing gradually toward a housing community of urbanization and high-rise. However, "EEWH" system for green building social indicators does not include the society, humanity and interaction factors, which can genuinely reflect the characteristics of high density and collective dwelling. Thus, the current system ignores users' real demand. This proposal firstly plans to collect the possible relevant impact factors, based on factors such as resident attitude, requirement, residence quality and interactions, and referred to other countries' indictor systems. Secondly, for clarifying the practical requirement and expectation of users and for strengthening the existing indicator system, the factor analysis method is used to generalize and extract the social dominant regional indicators. Since the evaluation of these dominant indicators requires subjective perception and is a fuzzy multi-attribute decision analysis (FMADA) problem with uncertainty, it is suitable to use the fuzzy extent analytic hierarchy process method. A hierarchical assessment framework is built, and the subjective qualitative values are transferred into objective and quantitative priority weightings by fuzzy pairwise comparison to reflect the degree of importance and evaluation efficacy. Finally, the proposed model is examined by implementing it on actual cases. The results should present clearly the priority of social interactions in these cases, and signify the concrete direction for improvement. In addition to strengthen the comprehensiveness of the existing green building assessment indicator system and to promote the quality of the entire dwelling environment effectively, the results of this research shall offer guidance for planning and design, and references for proposing and advancing relevant policies.
Keywords: Green Building Social Indicators, Housing Community, Factor Analysis (FA), Fuzzy Extent Analytic Hierarchy Process Method (FEAHP)

一、前言

在全球快速的變遷下，各國對於自身居住環境品質的要求無不受「永續發展」概念之影響與導引，進而依據自我地區的特質與需求，發展出具地方特色的評估工具以資因應；例如 CASBEE（日本）、BREEAM（英國）、LEED（美國）、GBC（加拿大…等國）、ESCALE（法國）、EcoEffect（瑞典）…等（張珩，2000；Todd et al., 2001, Olgyay and Herdt, 2004; Kim et al., 2005）。台灣地區因地狹人稠，高層化、高密度集居式之集合住宅社區已成為居住環境發展之主要形式；為能落實永續，政府部門特制訂「綠建築評估體系（EEWH 系統）」以資依循。然而，由於制訂初時，因政策之權宜方便而侷限於地球環保之緊急課題、又基於輔佐建築業者實務設計之立場，而暫時將相關於社會互動之因素予以摒除（林憲德，2005），造成忽略使用者之社會性需求與互動考量之現況缺憾。須知，社會性需求與互動的重視及考量乃是彰顯出各自地域性居住環境永續發展之重要地方行動（Act Locally）基礎；Brundtland（1987）早在聯合國揭櫫全球思考（Think globally）永續方向概念之前，即已明確地指出須將其察覺、釐清，並適切地反映於整體發展上之重要性與必要性（Chiu, 2004）。此外，透過社會性需求與互動的強調，除可有效維持社會關係穩定、落實社會福利實施，其也是支持環境生態延續之主要關鍵，以及成為未來居住環境之時代性指導原則（張珩，2003；Meikle and Dickson, 2006）。

相關於居住環境之社會性需求與互動所涉及的層面廣泛且複雜，其間不單純僅是居住者自身之需求與期待，尚且包含了居住者彼此間、以及與集居環境（建物、設施、空間）間整體之相互應對。Kohler（1999）即認為至少須能維護舒適與健康，並保持社會文化價值；GBC 2000 亦認為須指出使用者的舒適度標準、建物在社區的脈絡、社區認同、與服務管理…等（Boonstra, 2001）；Meikle 等人（2006）則指出須考量生活品質、人造設施、資源提供、居民社會互動、效應與衝擊…等的價值。因此，在面對建立綠建築社會性評估指標之研究課題上，首要在於能將上述偏屬於人類主觀感知、質化性質之實際居住環境特性、以及居住者需求加以明確地掌握；進而能將存在其間之主要特質與關係透過客觀、可量化的轉換予以釐清與界定。是以，本研究之目的在於：（一）建構一轉化主觀質性感知成客觀量化評比之系統性的評價流程，以作為研究操作之基礎。（二）客觀選擇並萃取出適切的關鍵影響因子，以建構出確切的評估指標。（三）藉由整體評價模式，檢驗所建立之綠建築社會性評價指標的可操作性。

二、研究架構

一般而言，評價須能有效歸納、解決在研究課題上所具有之多屬性特質；並於特質轉換為評估分析評比之過程中，要能有效處理因個人屬性、偏好所產生之價值判斷上無可避免的曖昧、含糊與不確定性（李允中等，2004）；是故，其本質係屬於模糊多屬性/準則決策分析（Fuzzy Multi-Attribute/Criteria Decision Analysis; FMADA/FMCDA）問題。在許多相關模糊多屬性決策分析研究（Chan et al., 2002; Hsu et al., 2003; Hsieh et al., 2004; Cochran and Chen, 2005）顯示，整合模糊理論於具清晰明確階層架構之模糊分析階層程序法（Fuzzy Analytic Hierarchy Process; FAHP）能有效地將主觀含糊、質化影響之決策問題，轉化為客觀明確、量化呈現的評價，並有效用以問題分析的執行（Büyüközkan et al., 2004）。

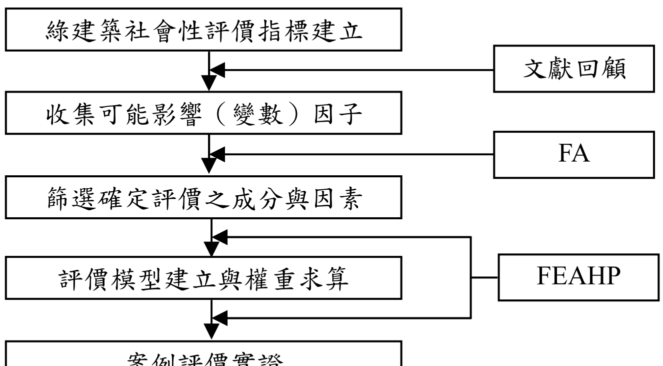

圖 1. 研究架構

本研究以相關綠建築評估指標、居住環境社會性需求與互動、以及本土地域性集居環境發展之實際需求與特質…等文獻回顧為基礎，先行彙整並歸納出相關可能影響（變項）因子。接著，藉由因素分析法（Factor Analysis; FA）萃取出具地區特色之社會性互動的主要成分，以作為強化既有指標系統之基礎。爾後，援引模糊延伸性分析階層程序法（FEAHP）先行建構出階層式評估架構；並進一步地導入實際案例予以驗證，整體研究架構見圖 1.。

三、研究方法

本研究以「因素分析法」與「模糊延伸性分析階層程序法」作為研究操作之主要方法，其相關操作步驟說明如下（Chang,1996; Wang et al., 2007; Wang et al., 2009）。

(一).因素分析法操作步驟（Chan et al., 2004; Wang et al., 2007; Wang et al., 2009）：

【步驟一】計算變項相關矩陣或共變異數矩陣：檢視是否適合進行因素分析？依取樣適切性量數 KMO 與 Bartlett 球形檢定值顯著性而定。

【步驟二】估計因素負荷量：採主成份分析、特徵值、與因素陡坡圖萃取之。

【步驟三】釐清因素間關係：使用最大變異轉軸法。

【步驟四】決定因素與命名：依據因素負荷量＞0.5 者。

【步驟五】信度分析：以 Cronbach's α 係數大於 0.7 為標準（吳明隆，2006）。

(二).模糊延伸性分析階層程序法操作步驟（Chan and Kumar, 2007; Chang, 1996; Wang et al., 2009; Zhu *et al.*, 1999）：

【步驟一】建立整體評比階層架構。

【步驟二】建立評比語意之三角模糊尺度：採 Zhu 等人（1999）尺度（見表 1.）。

表 1. 語意重要性尺度

語意重要性程度	三角模糊尺度（**l, m, u**）	三角模糊倒數尺度（**1/u, 1/m, 1/l**）
絕對同等重要	（1, 1, 1）	（1, 1, 1）
同等重要	（1/3, 1, 5/3）	（3/5, 1, 3）
稍微重要	（4/3, 2, 8/3）	（3/8, 1/2, 3/4）
很重要	（7/3, 3, 11/3）	（3/11, 1/3, 3/7）
非常重要	（10/3, 4, 14/3）	（3/14, 1/4, 3/10）
極度重要	（13/3, 5, 17/3）	（3/17, 1/5, 3/13）

Zhu *et al.*, 1999

【步驟三】建立 t 位評價者相關模糊成對比較矩陣 A：針對第（k-1）階層元素，第 k 階層內 n_k 個元素進行模糊成對比較，獲模糊判別矩陣（Chang,1996; Zhu *et al.*, 1999）：

$$A=\left(a_{ij}^{t}\right)_{n_k\times n_k}\ ,\quad a_{ij}^{t}=\left[l_{ij}^{t},m_{ij}^{t},u_{ij}^{t}\right];\quad i,j=1,2,\ldots,n_k\ ,\quad t=1,2,\ldots,T \tag{1}$$

【步驟四】整合各（k）階層各評價者模糊範圍分析值 (M_{ij}^{k})，求算模糊綜合範圍值 S_i：

$$M_{ij}^{k}=\frac{1}{T}\otimes\left(a_{ij}^{1}+a_{ij}^{2}+\cdots+a_{ij}^{T}\right) \tag{2}$$

$$S_j^{k}=\sum_{j=1}^{n}M_{ij}^{k}\otimes\left[\sum_{i=1}^{n_k}\sum_{j=1}^{n_k}M_{ij}^{k}\right]^{-1},\quad i=1,2,\ldots,n_k \tag{3}$$

【步驟五】比較模糊綜合範圍值 S_i：利用隸屬函數（M_i）之隸屬度（$\mu_{M_i}(x)$）表示出兩兩 M_i 間大小之可能性程度（DOP）的比較（$V(M_1\geq M_2)$）：

$$V(M_1\geq M_2)=\sup_{x\geq y}[\min(\mu_{M_1}(x),\mu_{M_2}(y))] \tag{4}$$

$$V(M_1\geq M_2)=1\quad \text{iff}\quad m_1\geq m_2$$
$$V(M_2\geq M_1)=\text{hgt}(M_1\cap M_2)=\mu(d) \tag{5}$$

$$\mu(d)=\begin{cases}\dfrac{l_1-\mu_2}{(m_2-u_2)-(m_1-l_1)}, & l_1\leqslant u_2,\\ 0, & \text{其他}\end{cases} \tag{6}$$

【步驟六】：藉 min $V(M_1 \geqq M_2)$求算各評價元素之權重向量（W'），再藉由標準化可求算出各評價元素之最終權重向量（W）：

$$\begin{aligned} & V(M \geq M_1, M_2, \ldots, M_k) \\ & = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \cdots \text{ and } (M \geq M_k)] \\ & = \min V(M \geq M_i), \quad i=1,2,\ldots,k \end{aligned} \tag{7}$$

令 $d'(A_i)=\min V(S_i \geq S_k),\ \ k=1,2,\ldots,n; k\neq i$ (8)

則，由方程式(4)可獲權重向量：$W'=(d'(A_1), d'(A_2), \ldots, d'(A_n))^T$ (9)

最終權重向量 $W=(d(A_1), d(A_2), \ldots, d(A_n))^T$ (10)

【步驟七】：方案實證、優劣排序。

四、研究操作

(一).社會性指標建立

本研究綜合相關文獻，並考量地區特質與居住者習性，先行歸納出影響社會性發展之生活設施…等四大條件構面；進而，於各構面之下彙整出相關之 53 項可能影響變數項目，如表 2.所示。

表 2. 研究變項歸納整理表

條件構面	可能影響變數項目		
生活設施條件	(1)充足、便利的停車空間	(2)街道空間（人行與汽、機車之獨立分行）	(3)高齡者、身心機能障礙者空間及相關設施
	(4)公共休閒空間	(5)綠地空間	(6)空間活化
	(7)大眾運輸系統	(8)交通便利性	(9)道路設施
	(10)公部門公共設施	(11)提升心靈或宗教場所規劃設置	(12)逃生避難設施
	(13)社區監視系統	(14)室內、外整體 E 化配備	(15)新穎科技設備
	(16)全區網路系統		
居住環境條件	(17)安寧性	(18)舒適感	(19)景觀美化與維護
	(20)環境健康衛生	(21)室內、外噪音控制	(22)建物外部條件
	(23)建物內部條件	(24)整體居住環境規劃設計	(25)居住環境的安全
	(26)建築物結構安全		
服務福利條件	(27)社會福利(由社區本身或政府提供)	(28)政府服務(行政效率、申訴管道…等)	(29)商業服務(日常性生活購物、7-11…等)
	(30)健康照顧(老弱婦孺日常性照護)	(31)醫療設施(輪椅、血壓計…等提供)	(32)保健活動(宣導、驗血、基本健檢…等)
	(33)政策法令	(34)社教文化推廣	(35)子女教育提供(教養諮詢、課後安親、才藝)
	(36)進修學習管道		
互動參與條件	(37)社區參與	(38)社區活動	(39)社區團結
	(40)地區聯誼	(41)社區服務	(42)鄰里關係
	(43)社交、互動性	(44)凝聚社區意識	(45)社區經營
	(46)社區環境維護	(47)社區設備維護	(48)自發性管理
	(49)學習空間	(50)舉辦社區學習活動	(51)社區關係價值觀念
	(52)自然資源價值觀念	(53)環境價值觀念	

接著，依表 2.採李克特五分量表（5-point Likert scale）製作問卷，並針對新竹地區集合住宅社區居住者進行調查。共計發放樣本 450 份，回收 324 份，其中有效問卷 307 份。回收問卷利用 SPSS 12.0 軟體以主成分分析；選取特徵值大於 1 的因素進行轉軸，其 Bartlett's

球型檢驗結果顯著（p-value＝0 < 0.01）、抽樣妥適度 KMO 值為 0.957，顯示相關研究問項適合進行因素分析。爾後，以旋轉後的因素負荷量絕對值大於 0.6、特徵值大於 1、以及因素陡坡圖為選取原則，歷經三次因素分析操作後，共計萃取出五個主要成分；依序（可解釋變異量高低）分別命名因素為「自發性互助參與(C_1)」、「環境安全舒適(C_2)」、「社會福利與服務(C_3)」、「公共空間多元化(C_4)」與「科技生活建置(C_5)」。相關之累積解釋變異量為 71.814％，各因素 Cronbach's α 值介於 0.756 至 0.960 之間（大於 0.7；屬高可信度），表示於建構綠建築社會性指標上將達一致性、整體 α 值為 0.97 亦具高可信度（詳見表 3.）。

表 3. 因素萃取表

可能影響變數項目	共同性	成分 1.	成分 2.	成分 3.	成分 4.	成分 5.
社區團結	0.776	0.827				
凝聚社區意識	0.787	0.811				
社區活動	0.755	0.805				
社區聯誼	0.744	0.786				
社區參與	0.751	0.781				
社交、互動性	0.720	0.778				
社區服務	0.710	0.772				
鄰里關係	0.731	0.758				
社區關係價值觀念	0.702	0.738				
舉辦社區學習活動	0.699	0.731				
社區經營	0.606	0.685				
自發性管理	0.598	0.672				
學習空間	0.700	0.657				
安寧性	0.786		0.857			
舒適感	0.801		0.854			
建築物結構安全	0.801		0.845			
居住環境的安全	0.792		0.835			
室內、外噪音控制	0.779		0.824			
環境健康衛生	0.758		0.800			
景觀綠美化與維護	0.734		0.763			
建物內部條件	0.644		0.740			
整體居住環境規劃設計	0.699		0.734			
充足、便利的停車空間	0.530		0.654			
建物外部條件	0.557		0.617			
醫療設施	0.806			0.811		
健康照顧	0.776			0.770		
保健活動	0.758			0.760		
子女教育提供	0.723			0.718		
進修學習管道	0.705			0.696		
政府服務	0.710			0.696		
社教文化推廣	0.748			0.673		
社會福利	0.668			0.672		
政策法令	0.631			0.620		
空間活化	0.637				0.715	
提升心靈或宗教場所規劃設置	0.622				0.711	
公共休閒空間	0.684				0.681	
室內、外整體E化配備	0.815					0.667
新穎科技設備	0.826					0.657
全區網路系統	0.736					0.631
Cronbach's α 值 (信度值)	個別	0.960	0.955	0.947	0.756	0.888
	整體			0.970		
特徵值		8.946	8.286	6.136	2.676	1.963
可解釋變異量(%)		22.937	21.247	15.735	6.861	5.033
總解釋變異量(%)				71.814 > 50 (O.K.)		
KMO 值				0.952 > 0.7 (O.K.)		
Bartlett's 球型考驗之 X^2(卡方\檢定)				11313.444 (具顯著)		

(二).評價模式建構

本研究課題係屬多準則決策分析，是以將問題拆解成目標（Goal）→屬性/準則（Attribute/Criteria）→方案（Alternatives）之階層式（Hierarchy）結構；而前述萃取出的五因素即為「屬性/準則」、未來實證所欲評比之集合住宅社區則被導入成為「方案」。同時，考慮於評價比較過程中必然存在之人類思維的含糊、不明確性，將於過程中導入模糊延伸性分析階層程序法進行評比，以建構出整體客觀之評價模式（圖 2.）。

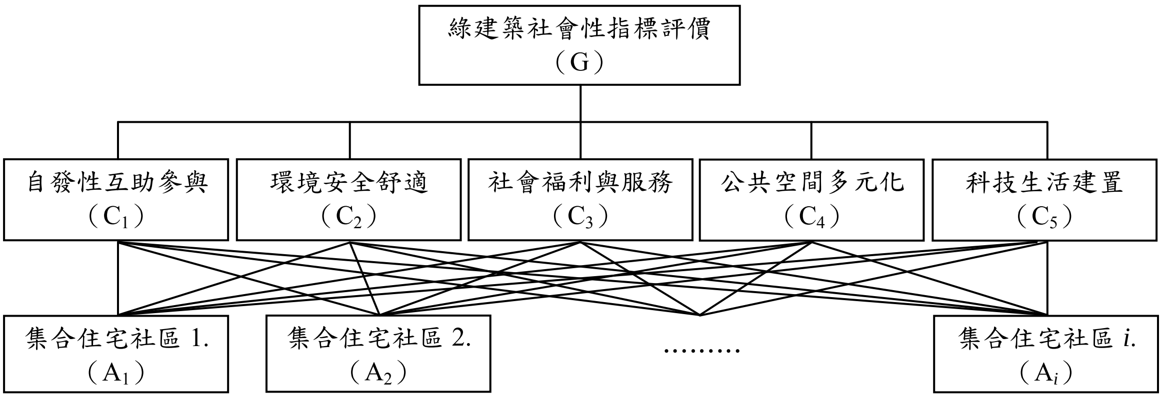

圖 2. 評價模式

(三).指標權重與案例驗證

本研究採專家問卷，透過產、官、學領域之五位專家進行模糊成對比較；除獲取前述五項因素（即萃取出的社會性指標）之重要性程度（權重）外，尚針對新竹地區具代表性之住宅社區案例（考量其隱私，分別以 A_1、A_2、A_3 表示）進行指標對應之實際驗證。

首先，針對五項指標因素（準則；$C_1, C_2, \cdots, C_5$），考量在「綠建築社會性指標評價」目標下，於專家模糊成對比較後，先行求算模糊範圍分析值與模糊綜合範圍值 S_i（表 4.）。爾後，再透過可能性程度（DOP）的比較（$V(M_1 \geqq M_2)$）求算出五項指標之權重向量 $W'_{準則}$（$W'_{準則}=(0.78, 1.00, 0.76, 0.57, 0.60)^T$）；進一步地，再藉由標準化求得最終權重向量 $W_{準則}$（$W_{準則}=(0.21，0.27，0.20，0.15，0.16)^T$）（見表 5.）。

表 4. 各準則模糊範圍分析值與模糊綜合範圍值

	C_1	C_2	C_3	C_4	C_5	$\sum_{j=1}^{m} M_{ij}^{k}$
C_1	(1, 1, 1)	(0.51, 0.80, 2.10)	(0.86, 1.10, 1.68)	(1.00, 1.50, 2.35)	(0.94, 1.50, 2.08)	(4.31, 5.90, 9.22)
C_2	(0.73, 1.40, 2.07)	(1, 1, 1)	(1.33, 2.00, 2.67)	(1.19, 1.80, 2.73)	(1.67, 2.20, 2.73)	(5.92, 8.40, 11.20)
C_3	(0.81, 1.10, 1.42)	(0.40, 0.57, 1.14)	(1, 1, 1)	(1.37, 1.87, 2.69)	(0.94, 1.50, 2.08)	(4.52, 6.03, 8.32)
C_4	(0.56, 0.90, 1.32)	(0.37, 0.60, 0.93)	(0.72, 1.03, 1.39)	(1, 1, 1)	(0.57, 1.00, 2.07)	(3.22, 4.53, 6.70)
C_5	(0.64, 0.97, 1.97)	(0.46, 0.53, 0.67)	(0.61, 0.90, 1.58)	(0.57, 1.00, 2.07)	(1, 1, 1)	(3.28, 4.40, 7.29)
$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$			(0.023, 0.034, 0.047)			
S_j^k	(0.10, 0.20, 0.43)	(0.14, 0.29, 0.53)	(0.11, 0.21, 0.39)	(0.08, 0.16, 0.32)	(0.08, 0.15, 0.34)	

表 5. 各準則可能性程度與權重值

	可能性程度(DOPs)	min $V(M \geq M_i)$	$W'_{準則}$	$W_{準則}$
C_1	(0.78, 0.99, 1.00, 1.00)	0.78	0.78	0.21
C_2	(1.00, 1.00, 1.00, 1.00)	1.00	1.00	0.27
C_3	(1.00, 0.76, 1.00, 1.00)	0.76	0.76	0.20
C_4	(0.82, 0.57, 0.80, 1.00)	0.57	0.57	0.15
C_5	(0.83, 0.60, 0.81, 0.98)	0.60	0.60	0.16

接著，針對實證案例 A_1、A_2、A_3 三社區，分別針對各項指標（C_1～C_5）進行方案間之兩兩模糊成對比較。於重複前階段求算各指標權重之步驟，可分別獲得各方案於各準則下之模糊範圍分析值（如表 6.所示）、各方案於各準則下之模糊綜合範圍值 S_i（見表 7.）、以及各方案於各準則下之權重表現（表 8.）。爾後，再將各方案於各準則下之權重表現與五項準則之最終權重向量（$W_{準則}$）加以整合，即可求算出實證案例相對應於「綠建築社會性指標評價」之優先權重，並可確切加以排序評比；其結果為：A_3（0.40）優於 A_2（0.31）優於 A_1（0.29）。

表 6. 各方案於各準則下之模糊範圍分析值

$\sum_{j=1}^{m} M_{ij}^{k}$	A_1	A_2	A_3	$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}$	$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$
C_1	(4.19, 5.09, 6.71)	(2.80, 3.35, 4.27)	(2.81, 3.57, 4.40)	(9.73, 12.01, 15.38)	(0.065, 0.083, 0.103)
C_2	(2.37, 2.91, 3.81)	(4.14, 5.20, 6.63)	(3.05, 3.73, 4.80)	(9.56, 11.85, 15.25)	(0.066, 0.084, 0.105)
C_3	(2.76, 3.56, 5.33)	(2.37, 2.98, 3.66)	(4.12, 5.10, 6.75)	(9.24, 11.64, 15.74)	(0.056, 0.086, 0.108)
C_4	(2.34, 2.82, 3.38)	(2.69, 3.38, 4.46)	(5.02, 6.00, 7.03)	(10.04, 12.21, 14.88)	(0.067, 0.082, 0.100)
C_5	(2.25, 2.82, 3.41)	(3.59, 4.27, 5.32)	(9.67, 11.64, 14.67)	(9.67, 11.64, 14.67)	(0.068, 0.086, 0.103)

表 7. 各方案於各準則下之模糊綜合範圍值

S_j^k	A_1	A_2	A_3
C_1	(0.27,0.42,0.69)	(0.18,0.28,0.44)	(0.18,0.30,0.45)
C_2	(0.16,0.25,0.40)	(0.27,0.44,0.69)	(0.20,0.32,0.50)
C_3	(0.18,0.31,0.58)	(0.15,0.26,0.40)	(0.26,0.44,0.73)
C_4	(0.16,0.19,0.23)	(0.18,0.23,0.30)	(0.34,0.40,0.47)
C_5	(0.15,0.24,0.35)	(0.24,0.37,0.55)	(0.26,0.39,0.61)

表 8. 各方案於各準則下之權重表現

	$W' = (A_1, A_2, A_3)^T$	W_{A1}	W_{A2}	W_{A3}
C_1	$(1.00，0.54，0.59)^T$	0.47	0.25	0.28
C_2	$(0.40，1.00，0.65)^T$	0.19	0.49	0.32
C_3	$(0.70，0.43，1.00)^T$	0.33	0.20	0.47
C_4	$(0.55，0.27，1.00)^T$	0.30	0.15	0.55
C_5	$(0.38，0.92，1.00)^T$	0.17	0.40	0.43

五、結論

透過文獻與他國施行體系之回顧、並考量地區特性與需求，所歸納出 53 項可能影響變數項目之涵蓋面甚具客觀性與廣泛性。繼而透過因素分析法之將影響變數與居住者感覺整合所萃取之五項主要成分，分別命名為「自發性互助參與」、「環境安全舒適」、「社會福利與服務」、「公共空間多元化」與「科技生活建置」的評價指標，可真實並適切地反映出本地區綠建築社會性之狀況，而有效強化既有 EEWH 系統之不足。

將萃取出的指標分別與評價目標、待評比社區以簡明易懂的階層式架構予以串連，並配合具有效解決人類感知含糊性之模糊延伸性分析階層程序法的成對比較，能將隸屬主觀、質性之感覺問題，系統且有效地轉換為客觀、量化的數學運算，而使整體實際驗證之評價模式極具實用性與可操作性。其表現於指標部分，可清楚地藉由排序與權重呈現出評價應用時指標彼此間的重要性程度：環境安全舒適（0.27）$\succ$自發性互助參與（0.21）$\succ$社會福利與服務（0.20）$\succ$科技生活建置（0.16）$\succ$公共空間多元化（0.15）。

該指標重要程度除可直接用以整合出社區間之整體優劣表現與評比排序（A_3（0.40）$\succ A_2$（0.31）$\succ A_1$（0.29））外，尚可藉由方案於各指標下之權重表現，提供社區自我檢測，彰顯出自我特色、明確掌握待強化之方向。例如：社區 A_1 在「自發性互助參與(0.47)」呈現出高度的向心力與歸屬感；但在安全舒適的環境建構(0.19)與科技生活設施的設置與供應(0.17)則有待加強。

整體而言，本研究主要之成果貢獻，除了所建立起的社會性指標可強化既有系統之完整性，使整合成為有效引導集居環境落實永續發展之依循標準外；其所建構之簡單明瞭的評價模式，更能為集居環境提供客觀且易操作的檢驗與評比，進而能適切地呈現出特色或未來調整改善之具體方向，有利於未來整體規劃設計與相關政策研擬推動時之參考。

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計畫成果自評

一.研究內容與原計畫之相符程度

本計畫主要目的在於建立起具地區特性的綠建築社會性指標，為求指標具操作性與鑑別性，特整合多準則決策分析概念，建立起系統性的客觀評價模式以供驗證執行；實際執行操作之整體研究架構，完全符合原始計畫之提案內容。

在計畫執行的過程上，除探討因素分析法（FA）與模糊延伸性分析階層程序法（FEAHP）的理論、操作步驟與演算流程外，更透過整合相關領域專家的意見，應用於地區實際案例的實際驗證，以獲取客觀的優劣排序與評比結果；整體研究內容、結果與原始提案計畫、目標相契合。

二.預期成果達成狀況

(一)綠建築社會性指標建立：透過因素分析法將相關文獻研究、他國體系、地區特性、以及居民態度與需求作系列的彙整、篩選與萃取，客觀地建構出確切、且可真實反映實際需求與互動的五項明確指標。

(二)指標重要性程度的呈現：藉由模糊延伸性分析階層程序法，適切地將模糊多準則決策分析概念應用於既已建立指標的評比上；透過專家意見的整合，清楚地將各指標的重要性程度以權重數值的方式予以呈現、排序。

(三)整體評價模式的建構與實證：結合於住宅社區案例之間的評價，明確地建構出能將隸屬主觀、不確定性的認知問題，有效轉化為客觀、明確量化表示的評價模式。研究成果可藉由各案例對應於目標、各指標之權重數值，分別明確地表示出各案例對應於整體目標的優劣評比、以及對應於各指標之發展現況的評價排序，該研究預期成果之達成狀況甚佳。

三.研究成果之貢獻

(一)五項指標之建立除可直接結合於既有綠建築評估體系，有效強化現狀於社會性層面的不足外；其個別重要性程度數值，尚可供日後實際發展的規劃與相關政策研擬時之參考。

(二)所建構之評價模式不僅可為居住環境的永續發展落實，提供客觀具體、適切且具可操作性的評比依循；相關評價結果還可作為居住環境自我檢驗、研擬調整改善之明確依循。

四.研究成果之發表

本計畫研究成果已發表於國際性研討會：

Wang, W.M., Lee, A.H.I. and Chang, D.T. (2009). An integrated FA-FEAHP approach on the social indicators of Taiwan's green building. Business & Economics Society International 2009 Hawaii-USA Conference, July 15-19, 2009, pp. 1-11, Kona Hawaii, USA.

附件一

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

98 年 **8** 月 **1** 日

報告人姓名	**王　維　民**	服務機構 及職稱	**中華大學 建築與都市計畫學系 講師**
時間 會議 地點	**98.07.15.～98.07.19. Kona-Hawaii, USA**	本會核定 補助文號	**臺會綜二字第 0970036137 號 (97.07.01.) (NSC 97-2410-H-216-008)**
會議 名稱	（中文） （英文）**Business & Economics Society International 2009 Hawaii-USA Conference**		
發表 論文 題目	（中文） （英文）**An Integrated FA-FEAHP Approach on the Social Indicators of Taiwan's Green Building**		

報告內容應包括下列各項：

一、參加會議經過

因考量 H1N1 新型流感疫情影響，依 貴會 98.06.09.臺會綜二字第 0980039325 號函辦理，僅報名該國際學術會議之投稿，而未出席。

二、與會心得

三、考察參觀活動(無是項活動者省略)

四、建議

五、攜回資料名稱及內容

六、其他

附件二

An Integrated FA-FEAHP Approach on the Social Indicators of Taiwan's Green Building

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ABSTRACT

Green building indicator system has become an essential instrument for fulfilling the sustainable development of collective residence environment. Under the action principle of "Global thinking, Local action", the indicator system should reflect local characteristics and requirements, and must possesses extensity. However, the followed norm in Taiwan does not contain the related social impact factors that reflect the characteristics of high density and collective dwelling. Therefore, this paper first collects the relevant possible impact factors based on the inhabitant users' information, local characteristics, and other indicator systems. Then, factor analysis method (FA) is employed to investigate the users and to extract the principal components of social impact with regional characteristics. Then, the social indicator establishment and application problem is solved by applying the fuzzy extended analytic hierarchy process method (FEAHP). Finally, by integrating the examination of actual cases, a hierarchical assessment framework is built. The subjective qualitative values for indicators are transferred into objective and quantitative priority weights by fuzzy pairwise comparison to reflect the degree of importance and evaluation efficacy. The results of this research not only strengthen the comprehensiveness of the existing green building indicator system, but also signify the concrete direction for improvement for evaluated cases.

Keywords: Green Building Social Indicators, Housing Community, Factor Analysis (FA), Fuzzy Extended Analytic Hierarchy Process (FEAHP)

1. Introduction

Green building indicator system is a vital instrument in many countries/regions – Japan's CASBEE, UK's BREEAM and Canada's GBC for example (Todd, Crawley, Geissler, & Lindsey, 2001). If established completely, the system can be used to improve life quality and residence satisfaction, and increase benefit in every aspect of collective residence environment (CRE), (Wang, Chang, & Lee, 2007a). The fulfillment of sustainable development (SD) of CRE, whether it is explicit or tacit, is a necessary prerequisite for the success in today's dynamic and changing life. Under the guidance of "Global thinking, Local action" of SD, a good indicator system needs to meet local characteristics and demands (Boonstra, 2001; Todd & Geissler, 1999).

Owing to the limitation of small area and dense population in Taiwan, housing community (HC) has become the fundamental unit for overall residential environment and urban development (Huang, 2006; Wang, Chang, & Lee, 2007b). For forging ahead sustainability in the rapidly changing process under high urbanization, industrialization and technology, the government has established the EEWH system as a standard. However, the standard ignores factors relating to social interaction in the first place (Lin, 2001), and thus neglects dweller-oriented social needs.

In general, the social interaction is complex and is influenced by many factors in real life. It is necessary to take various aspects of residence-environment factors into consideration when dealing with the interaction between living-environment and occupants (Chiang & Lai, 2002). Because of its ability to effectively reduce data into comprehensible measurements and to systematically measure success in a standardized fashion, the social assessment indicators have been established and applied popularly (Wedding & Crawford-Brown, 2007). Since such indicators have generally been developed with the consideration of the cooperation among occupants, the indicators have their practical value. However, the relevant factors, influence and occupants' use are vague and uncertain, and involve human cognition and subjective judgment. The establishment of social indicators of green building is a fuzzy multi-attribute decision analysis (FMADA) problem in nature.

This paper presents the methodology of developing comprehensive social indicators for CRE assessment by integrating factor analysis method (FA) with fuzzy extended analytic hierarchy process (FEAHP). FA is used to extract the principal components of social impact with local characteristics and occupants' needs/expectation to be indicators/criteria. And then, a hierarchical assessment framework is built, and FEAHP is employed to examine of actual cases. The purpose of this paper is to amend the deficiency of current indicator systems and to provide the occupants with measures of social interaction and actual expectations for promoting CRE quality.

2. Indicators derivation

This study first gathered possible impact variables of dwelling needs and lifestyle of occupants and dwelling environment quality from relevant literature and research (Chiu, 2004; Ge & Hokao, 2006; Kohler, 1999; Marans, 2003; Raphael, Renwick, Brown, Steinmetz, Sehdev, & Phillips, 2001), and compared them with the existing systems of other countries (Boonstra, 2001; Cole, 1999; Edmunds, 1999; Grace, 2000; Kim et al., 2005; Olgyay & Herdt, 2004; Todd et al., 2001).

From the results of Wang et al. (2007a), 53 variables were generalized, and FA was applied next to extract five principal components of social impact with regional characteristics. In the process of FA, 5 variables have factor loadings of less than 0.5, and 11 variables are single factors. Therefore, these 16 variables were deleted. In the sequence of importance, the principal components were denominated separately as Spontaneous interactive participation (SIP), Health and welfare (HAW), Overall residential environment (ORE), High-tech surveillance equipment (HSE), and Open public area (OPA), as shown in Table 1. These principal components are transformed into assessment indicators/criteria for follow-up research.

3. FEAHP method and evaluation model

Many works on FMADA (Bozbura, Beskese, & Kahraman, 2007; Chang, Wu, & Chen, 2008; Cheng, Chen, & Chen, 2008; Kuo, Liang, & Huang, 2006; Wang, Chu, & Wu, 2007) showed that the fuzzy AHP (FAHP) could assist effectively in tackling the uncertainty and vagueness in subjective perception and in evaluation and decision process. In addition, Chang (1996) proposed that FAHP with extent analysis is simple and easy for implementation to prioritize decision variables as compared with other FAHP methods (Bozbura & Beskese, 2007; Kwong & Bai, 2003). The method is easier to understand and can effectively handle both qualitative and quantitative data in multi-attribute decision making problems by using linguistic assessment (Chan & Kumar, 2007). In more recent years, the method was applied to relevant research fields broadly (Bozbura & Beskese, 2007; Buyukozkan, Kahraman, & Ruan, 2004; Erensal, Oncan, & Demircan, 2006; Kahraman, Ertay, & Buyukozkan, 2006).

TABLE 1. The extracted principal components (Wang et al., 2007a)

Principal Components / Loading / Variables	Spontaneous interactive participation (SIP)	Health and welfare (HAW)	Overall residential environment (ORE)	High-tech surveillance equipment (HSE)	Open public area (OPA)
	5 principal components extracted				
Space and relevant facilities for the aged and physically-challenged people	0.196	0.034	0.115	0.040	0.849
Public recreational space	0.366	0.185	-0.019	0.113	0.801
Greenfield	-0.041	0.170	0.204	-0.113	0.869
Space vitality	0.280	0.138	0.235	0.058	0.773
Emergency facility	0.174	0.412	0.057	0.651	-0.186
New surveillance system	0.000	0.062	0.094	0.894	-0.013
Indoor and outdoor electronic equipment	-0.041	0.069	0.184	0.809	0.039
High-tech equipment	0.035	-0.188	0.228	0.787	0.184
Electronic network system	-0.057	0.152	0.215	0.752	0.001
Comfort of environment	0.181	0.002	0.612	-0.250	0.235
Landscape and maintenance of residential environment	0.277	0.034	0.685	0.013	0.325
Environmental health and hygiene	0.114	0.166	0.778	0.125	0.329
Indoor and outdoor noise	-0.061	0.093	0.789	0.261	0.129
External conditions of building	-0.007	0.075	0.614	0.090	-0.015
Internal conditions of building	-0.006	0.056	0.801	-0.041	-0.030
Planning & design of dwelling environment	-0.006	0.036	0.849	0.213	0.206
Safety of residential environment	-0.023	0.189	0.806	0.320	-0.079
Structural safety of building	0.062	0.185	0.841	0.201	-0.145
Social welfare	0.357	0.791	0.026	0.106	0.139
Governmental service	0.333	0.806	0.185	0.078	0.160
Commercial service	0.024	0.841	0.053	0.174	0.000
Medical and health care	0.191	0.856	0.223	-0.132	0.029
Medical treatment facility	0.149	0.856	0.142	0.043	0.137
Activities of medical health protection	0.252	0.861	0.000	0.109	0.071
Policy and ordinance	0.290	0.747	0.184	-0.032	0.002
Community participation	0.882	0.099	0.092	-0.176	0.136
Community activity	0.845	0.267	-0.083	-0.039	0.257
Community unity	0.944	0.130	0.069	-0.055	0.006
Regional communication	0.892	0.021	-0.043	0.014	0.202
Community service	0.869	0.135	0.100	0.102	0.061
Neighbor's relation	0.722	0.414	-0.016	0.031	0.059
Social contact and interaction	0.762	0.311	0.092	0.114	0.151
Agglomerate community consciousness	0.824	0.229	0.073	0.131	0.112
Community conduct	0.866	0.193	-0.067	-0.078	0.105
Spontaneous management	0.702	0.189	-0.032	-0.155	-0.059
Community learning space	0.576	0.384	0.151	0.034	0.046
Values of community relation	0.539	0.492	0.116	0.122	-0.021

After the assessment indicators/criteria are obtained, actual cases of HC are next added to be the alternatives (A_1, A_2, …, A_n), and then a hierarchical assessment model with three levels is built (see Figure 1). Subsequently, the FEAHP is employed to the empirical study. The FEAHP uses triangular fuzzy numbers (TFNs) to represent evaluators' or decision makers' comparison judgments and fuzzy synthetic extent analysis method to determine the final priorities of different criteria (Chan & Kumar, 2007; Kahramana, Cebeci, & Ruan, 2004; Zhu, Jing, & Chang, 1999).

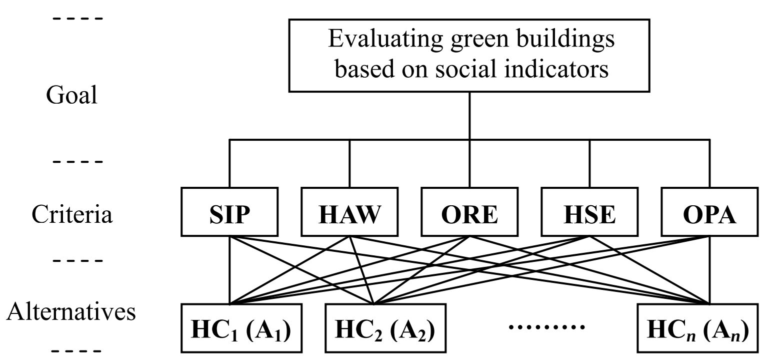

FIGURE 1. Assessment Model

Chang's (1996) method is briefly introduced here (Bozbura & Beskese, 2007; Chan & Kumar, 2007; Kahramana et al., 2004). Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, and $U = \{u_1, u_2, \ldots, u_m\}$ be a goal set. Each object is taken, and extent analysis for each goal (g_i) is performed, respectively (Chang's, 1996). Therefore, m extent analysis values for each object are obtained:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \quad i = 1, 2, \ldots, n \qquad (1)$$

All the $M_{g_i}^j$ (j = 1, 2, …, m) are TFNs. Chang (1996) defined a TFN M on R if its membership function $\mu_M(x)$: R → [0,1] is equal to

$$\mu_M(x) = \begin{cases} \dfrac{x}{m-l} - \dfrac{l}{m-l}, & x \in [l, m] \\ \dfrac{x}{m-u} - \dfrac{u}{m-u}, & x \in [m, u] \\ 0, & \text{otherwise} \end{cases} \qquad (2)$$

A TFN is denoted as (l, m, u), in which l, m and u represent the lowest possible value, the most possible value, and the largest possible value respectively. The algebraic calculations of two TFNs (Chang, 1996; Tsaur, Chang, & Yen, 2002) are as follows:

1. Addition: $(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1+l_2, m_1+m_2, u_1+u_2)$ (3)

2. Multiplication: $(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2)$ (4)

3. Any real number λ: $(\lambda, \lambda, \lambda) \otimes (l_1, m_1, u_1) = (\lambda l_1, \lambda m_1, \lambda u_1)$ (5)

4. Reciprocal: $(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1)$ (6)

The steps of Chang's FEAHP are as follows (Chang, 1996; Bozbura & Beskese, 2007; Zhu et al., 1999):

Step 1: Define the linguistic scale by a triangular fuzzy scale (see Table 2). This research adopts the scale from Zhu et al. (1999).

TABLE 2. Triangular fuzzy conversion scale (Zhu et al. (1999)

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/3, 1, 5/3)	(3/5, 1, 3)
Weakly more important	(4/3, 2, 8/3)	(3/8, 1/2, 3/4)
Strongly more important	(7/3, 3, 11/3)	(3/11, 1/3, 3/7)
Very strongly more important	(10/3, 4, 14/3)	(3/14, 1/4, 3/10)
Absolutely more important	(13/3, 5, 17/3)	(3/17, 1/5, 3/13)

Step 2: Construct the fuzzy judgment matrix (A) by fuzzy pairwise comparison from T experts. For the (k-1)th layer, there are m related factors in the kth layer. When these m factors are fuzzy pairwise compared, a fuzzy judgment matrix is obtained:

$$A^t = \left(a_{ij}^t\right)_{n\times m};\quad a_{ij}^t = \left[l_{ij}^t, m_{ij}^t, u_{ij}^t\right];\quad i = 1, 2, \ldots, n; j = 1, 2, \ldots, m;$$

for each t, $t = 1, 2, \ldots, T$ (7)

Step 3: Calculate the fuzzy synthetic extent value (S_j^k) of the (k-1)th layer by integrating the fuzzy m extent analysis values of the kth layer (M_{ij}^k) from T experts.

$$M_{ij}^k = \frac{1}{T} \otimes \left(a_{ij}^1 + a_{ij}^2 + \cdots + a_{ij}^T\right) \tag{8}$$

$$S_j^k = \sum_{j=1}^{m} M_{ij}^k \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}^k\right]^{-1} ;\quad i = 1, 2, \ldots, n;\quad j = 1, 2, \ldots, m \tag{9}$$

Step 4: Calculate the degree of possibility (DOP)-$V(M_2 \geq M_1)$ of S_j^k. The DOP of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y)] \tag{10}$$

And, it can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \tag{11}$$

where d is the ordinate of the highest intersection point D between μ_{M_2} and μ_{M_1} (Fig. 2).

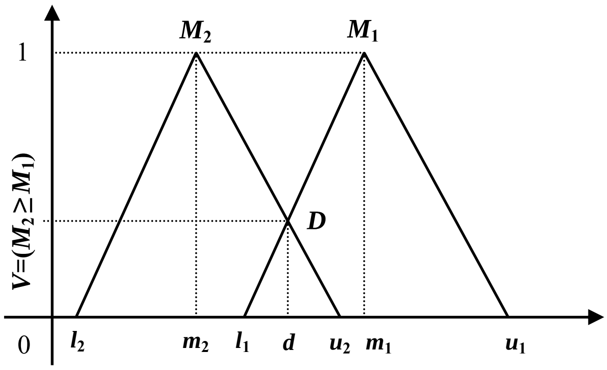

FIGURE 2. The intersection between M_1 and M_2. (Chang, 1996)

Step 5: Calculate the weight vector ($\boldsymbol{W}$) of each evaluation criterion by min $V(M \geq M_i)$ and normalization. The DOP for a convex fuzzy number to be greater than k convex fuzzy numbers M_i ($i = 1, 2, \ldots, k$) can be defined by

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } (M \geq M_k)]$$
$$= \min V(M \geq M_i),\quad i = 1, 2, \ldots, k \tag{12}$$

There are n evaluation criteria, denoted as A_i ($i = 1, 2, \ldots, n$). Assume that
$d'(A_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, \ldots, n$; $k \neq i$. (13)

Then the weight vector ($\boldsymbol{W}$) is given by
$\boldsymbol{W}' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T$ (14)

The final weight vector ($\boldsymbol{W}$) is obtained by normalization:
$\boldsymbol{W} = (d(A_1), d(A_2), \ldots, d(A_n))^T$ (15)

Step 6: Evaluate and rank the performances of the alternatives. The priorities of the cases could be derived from repeating Step 2 to Step 5.

4. Empirical verification of FEAHP

This research uses a face-to-face survey to collect opinions of seven experts. These experts came from industry (e.g. planning and design, community and property management), government departments (e.g. urban planning/design and buildings management), and professional scholars from related fields to contribute their expertise.

Firstly, based on the assessment model (shown in Figure 2), fuzzy pairwise comparison of goal and criteria are performed by experts, the fuzzy judgment matrix of all the criteria with respect to the goal are obtained (see Table 3).

And then, the average of seven extent analysis values (M_{ij}^{k}) and $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$ are calculated by equations (3), (5), (6), and (8), and the related results are as shown in Table 4.

TABLE 3. The fuzzy judgment matrix

	SIP	HAW	ORE	HSE	OPA
	(1, 1, 1)	(3/5, 1, 3)	(3/8, 1/2, 3/4)	(4/3, 2, 8/3)	(3/11, 1/3, 3/7)
		(4/3, 2, 8/3)	(3/8, 1/2, 3/4)	(4/3, 2, 8/3)	(1/3, 1, 5/3)
		(7/3, 3, 11/3)	(3/11, 1/3, 3/7)	(7/3, 3, 11/3)	(3/5, 1, 3)
SIP		(3/11, 1/3, 3/7)	(3/14, 1/4, 3/10)	(3/5, 1, 3)	(3/11, 1/3, 3/7)
		(3/14, 1/4, 3/10)	(3/8, 1/2, 3/4)	(1, 1, 1)	(3/8, 1/2, 3/4)
		(4/3, 2, 8/3)	(10/3, 4, 14/3)	(13/3, 5, 17/3)	(4/3, 2, 8/3)
		(3/5, 1, 3)	(1,1,1)	(3/11, 1/3, 3/7)	(3/14, 1/4, 3/10)
	(1/3, 1, 5/3)	(1, 1, 1)	(3/11, 1/3, 3/7)	(1/3, 1, 5/3)	(3/11, 1/3, 3/7)
	(3/8, 1/2, 3/4)		(3/8, 1/2, 3/4)	(1/3, 1, 5/3)	(3/11, 1/3, 3/7)
	(3/11, 1/3, 3/7)		(3/5, 1, 3)	(4/3, 2, 8/3)	(3/5, 1, 3)
HAW	(7/3, 3, 11/3)		(3/5, 1, 3)	(1/3, 1, 5/3)	(3/8, 1/2, 3/4)
	(10/3, 4, 14/3)		(3/11, 1/3, 3/7)	(3/8, 1/2, 3/4)	(3/8, 1/2, 3/4)
	(3/8, 1/2, 3/4)		(1/3, 1, 5/3)	(4/3, 2, 8/3)	(3/8, 1/2, 3/4)
	(1/3, 1, 5/3)		(3/5, 1, 3)	(3/8, 1/2, 3/4)	(3/11, 1/3, 3/7)
	(3/5, 1, 3)	(7/3, 3, 11/3)	(1, 1, 1)	(4/3, 2, 8/3)	(4/3, 2, 8/3)
	(4/3, 2, 8/3)	(4/3, 2, 8/3)		(4/3, 2, 8/3)	(1/3, 1, 5/3)
	(7/3, 3, 11/3)	(1/3, 1, 5/3)		(4/3, 2, 8/3)	(3/5, 1, 3)
ORE	(10/3, 4, 14/3)	(1/3, 1, 5/3)		(3/5, 1, 3)	(7/3, 3, 11/3)
	(4/3, 2, 8/3)	(7/3, 3, 11/3)		(1, 1, 1)	(3/5, 1, 3)
	(3/14, 1/4, 3/10)	(3/5, 1, 3)		(4/3, 2, 8/3)	(3/11, 1/3, 3/7)
	(1, 1, 1)	(1/3, 1, 5/3)		(4/3, 2, 8/3)	(7/3, 3, 11/3)
	(3/8, 1/2, 3/4)	(3/5, 1, 3)	(3/8, 1/2, 3/4)	(1, 1, 1)	(3/8, 1/2, 3/4)
	(3/8, 1/2, 3/4)	(3/5, 1, 3)	(3/8, 1/2, 3/4)		(3/8, 1/2, 3/4)
	(3/11, 1/3, 3/7)	(3/8, 1/2, 3/4)	(3/8, 1/2, 3/4)		(3/11, 1/3, 3/7)
HSE	(1/3, 1, 5/3)	(3/5, 1, 3)	(1/3, 1, 5/3)		(3/17, 1/5, 3/13)
	(1, 1, 1)	(4/3, 2, 8/3)	(1, 1, 1)		(1, 1, 1)
	(3/17, 1/5, 3/13)	(3/8, 1/2, 3/4)	(3/8, 1/2, 3/4)		(3/14, 1/4, 3/10)
	(7/3, 3, 11/3)	(4/3, 2, 8/3)	(3/8, 1/2, 3/4)		(4/3, 2, 8/3)
	(7/3, 3, 11/3)	(7/3, 3, 11/3)	(3/8, 1/2, 3/4)	(4/3, 2, 8/3)	(1, 1, 1)
	(3/5, 1, 3)	(7/3, 3, 11/3)	(3/5, 1, 3)	(4/3, 2, 8/3)	
	(1/3, 1, 5/3)	(1/3, 1, 5/3)	(1/3, 1, 5/3)	(7/3, 3, 11/3)	
OPA	(7/3, 3, 11/3)	(4/3, 2, 8/3)	(3/11, 1/3, 3/7)	(3/11, 1/3, 3/7)	
	(4/3, 2, 8/3)	(4/3, 2, 8/3)	(1/3, 1, 5/3)	(1, 1, 1)	
	(3/8, 1/2, 3/4)	(4/3, 2, 8/3)	(7/3, 3, 11/3)	(10/3, 4, 14/3)	
	(10/3, 4, 14/3)	(7/3, 3, 11/3)	(3/11, 1/3, 3/7)	(3/8, 1/2, 3/4)	

TABLE 4. The values of $\sum_{j=1}^{m} M_{ij}^{k}$ and $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$

	SIP	HAW	ORE	HSE	OPA	$\sum_{j=1}^{m} M_{ij}^{k}$
SIP	(1, 1, 1)	(0.96, 1.37, 2.25)	(0.85, 1.01, 1.24)	(1.60, 2.05, 2.73)	(0.49, 0.77, 1.32)	**(4.89, 6.20, 8.53)**
HAW	(1.05, 1.48, 1.94)	(1, 1, 1)	(0.44, 0.74, 1.75)	(0.63, 1.14, 1.69)	(0.36, 0.50, 0.93)	**(3.48, 4.86, 7.32)**
ORE	(1.45, 1.89, 2.57)	(1.09, 1.71, 2.57)	(1, 1, 1)	(1.18, 1.71, 2.48)	(1.12, 1.62, 2.59)	**(5.83, 7.94, 11.2)**
HSE	(0.70, 0.93, 1.21)	(0.75, 1.14, 2.26)	(0.46, 0.64, 0.92)	(1, 1, 1)	(0.84, 1.08, 1.37)	**(3.74, 4.80, 6.76)**
OPA	(1.52, 2.07, 2.87)	(1.62, 2.29, 2.95)	(0.65, 1.02, 1.66)	(1.43, 1.83, 2.26)	(1, 1, 1)	**(6.21, 8.21, 10.74)**
$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$						**(0.022, 0.031, 0.041)**

After the fuzzy synthetic extent values (S_j^k) are obtained (shown as Table 5) through equation (9), this research can proceed to calculate the DOP of each S_j^k by equations (10) and (11). And then, the weight vector (***W′***) of each evaluation criteria can be acquired by equations (12), (13) and (11). Finally, the final weight vector (***W***) is calculated through normalization. The related results of DOPs, ***W′*** and ***W*** are summarized in Table 6.

TABLE 5. The fuzzy synthetic extent values (S^k_i) of criteria

	SIP	HAW	ORE	HSE	OPA
$\sum_{j=1}^{m} M_{ij}^{k}$	(4.89, 6.20, 8.53)	(3.48, 4.86, 7.32)	(5.83, 7.94, 11.2)	(3.74, 4.80, 6.76)	(6.21, 8.21, 10.74)
$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}^{k}\right]^{-1}$			(0.022, 0.031, 0.041)		
S_j^k	(0.11, 0.19, 0.35)	(0.08, 0.15, 0.30)	(0.13, 0.25, 0.46)	(0.08, 0.15, 0.28)	(0.14, 0.26, 0.44)

TABLE 6. The values of DOPs, *W′* and *W*

	DOPs	min $V(M \geq M_i)$	*W′*	*W*
SIP	(1.00, 0.80, 1.00, 0.77)	0.77	0.77	**0.197**
HAW	(0.82, 0.64, 1.00, 0.61)	0.61	0.61	**0.155**
ORE	(1.00, 1.00, 1.00, 0.97)	0.97	0.97	**0.248**
HSE	(0.80, 0.99, 0.60, 0.57)	0.57	0.57	**0.145**
OPA	(1.00, 1.00, 1.00,1.00)	1.00	1.00	**0.255**
W′	**$(0.77, 0.61, 0.97, 0.57, 1.00)^T$**			
W	**$(0.197, 0.155, 0.248, 0.145, 0.255)^T$**			

Based on the assessment model and the systematical algorithm, the priority of each social indicator can be obtained, and the performance ranking of evaluated alternatives can be generated.

5. Conclusions

With increasing globalization and stronger public awareness in living environmental quality and demands, a comprehensive list of green building indicators today simply cannot ignore social issues if a high quality of CRE needs to be achieved sustainably. In addition, a comprehensive list of green building indicators must be prepared with the consideration of occupants' self-satisfaction and interaction among occupants, and government should keep in mind that the establishment of a perfect green-building indicator system is essential for guidance and implementation in SD of CRE.

This paper proposes a hierarchical assessment model, which integrates the social influences on Taiwan's CRE and reflects the effectiveness of indicators. FEAHP is a suitable method because of its strength in taking into account the vagueness of experts' opinions in the evaluation process while applying the Saaty's AHP. The results show that the social evaluating indicators (and their priorities) are spontaneous interactive participation (0.197), health and welfare (0.155), overall residential environment (0.248), high-tech surveillance equipment (0.145), and open public area (0.255). In addition, the research reveals three major outcomes. First, the assessment model is clear, easy to understand and execute. In the future, when the actual HC cases are added to be alternatives, the model can be used to evaluate the alternatives and to help devise improved strategies. Second, the process could effectively transform uncertain and qualitative problems into explicit and quantitative evaluation of indicators by considering the local characteristics and occupants' demands. Third, it could examine the implementation of the social indicators more specifically and practically.

To sum up, the results from this research not only can strengthen the comprehensiveness of the existing green building indicator system, but also can signify the concrete direction for improvement for evaluated cases. In addition, the results shall offer definite guidance for planning and design, and references for proposing and advancing relevant policies in the future.

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