SELECTION OF MOST ECONOMICAL GREEN BUILDING OUT OF n-ALTERNATIVES: APPROACH OF VAGUE FUZZY LOGIC

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Abstract

*The concept of green building are now very effective tool to an engineer for construction of a new building and plays a vital role to influence his decision towards saving of water & electricity, providing healthier spaces, and generate less quantity of wastes during constructional period[3]. The quality and quantity of materials are directly gives the output efficiency in respect of the economy as well as positive environmental condition of a green building. But it is often found that total cost of building and total environmental impact values (**TEIV**) (inside and outside) are not same for all buildings constructed in various places due to fluctuation of market rate from place to place[4]. Thus to define a most economical green building out of n-alternatives, total cost of the building and it's TEIV are very essential factors for assessment and making rank among them. But it is not a easy job because most of the data are not always crisp or numeric rather linguistic and hedges like 'high reflective roof coating', 'bad orientation', 'poor sanitation', 'very good environmental quality', 'cheap materials', 'good drainage system', 'heavy rainfall', 'high energy consumption', etc. to list a few only out of infinity. All these data are fuzzy in nature thus evaluation of many objects here is not possible with numerical valued descriptions[1]. All experts' perception towards giving his decision depends wholly on his neural network functions which fluctuate according to the nature of function of dendrite and axon. Thus every decision-maker hesitates more or less on every evaluation activity which needs to be eliminated. The fuzzy logic has now proved worldwide as a tremendous tool to tackle this situation. This paper presents a fuzzy modelling for selection of most economical green building (GB) out of n-alternatives more precisely.*

Keywords: *attributes, fuzzy decision, TEIV, vague fuzzy EIA, etc.*

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1. INTRODUCTION

In economical green building the efforts are given on the concept of getting the best positive environmental efficiency and minimise the overall cost of building. But practically it is often found that if two buildings constructed on same plan, design & orientation in two separate cities, one may be environmentally efficient building but may not be declared as economical one and similarly the vice versa also. The market rate of land and materials are not same in all places or cities. Even the existing environmental conditions of all cities are also not same rather dramatically varies from one to one[4,5]. Thus it is a great problem to an engineer or expert to predict a building as most economical green building out of n-alternatives. Because this kind of prediction involves uncertainty that influence the overall decision of the expert. Most of the judgments are done by human being or intelligent agent who has certainly a limitation of knowledge or intellectual functionaries to tackle this type of uncertainty. Naturally some part of his judgement contributes to truthness and some part contributes to falseness[1]. An engineer can feel much more confidence and can better guess a degree of belongingness or a degree of non-belongingness independently within the interval [1,0] instead of defining the building as 'most economical' or 'extremely green' or 'less polluted' etc. For assessment of a green building with degree of certainty the data are often found like 'high reflective roof coating', 'bad orientation', 'poor sanitation', 'good indoor environmental quality', 'low constructional cost', 'good drainage system', 'heavy rainfall', 'high energy consumption', 'poor insulation', etc. out of many. All these data are linguistic variable and evaluation can't be done properly due to involvement of uncertainty. As a result the satisfaction of the engineer are not found upto his desired level. But if the data are evaluated in degree of belongingness within the interval [1,0], the uncertainty can be avoided as far as possible and result will get more precisely then the earlier. Thus to tackle the uncertainty it is very essential to introduce fuzzy logic for assessment the quantification of quality of a green building. In this paper composed fuzzy model of 'Vague Fuzzy EIA' and 'Fuzzy Decision' has been introduced 'to minimise the uncertainty involved in the selection of most economical Green Building out of alternatives.

2. PRELIMINARIES

In this chapter some preliminaries are discussed which will be very useful in composed fuzzy model of 'Vague Fuzzy EIA' and 'Fuzzy Decision' tool.

2.1 Fuzzy Sets (FS) and Fuzzy Logic [6]

The concept of uncertainty has a vital role in the solution of our daily life problems and thus needs to tackle it properly. Prof. Latfi Zadeh first laid the foundation of fuzzy set theory in 1965 by generalization of ordinary crisp set theory. According to his concept, when a statement is completely true then the membership value is 1 and when a statement is completely false the membership value is 0 and when the statement is partially true and partially false then the membership value will be in between 0 and 1. Thus the membership function of a fuzzy sets can take any value form the closed interval [0,1]. It is expressed as the set of ordered pairs like $A = \{ (x_1, \mu_A(x_1)), (x_2, \mu_A(x_2)), ….. , (x_n , \mu_A(x_n)) \}$, where $\mu_A(x_i)$, is the grade of membership of element x_i in set A. The greater value of $\mu_A(x_i)$, indicates greater the truthness of statement that 'the element x_i belongs to set A'.

2.2 Vague Fuzzy Set (VFS) [2]

A vague set A in the universe of discourse U is characterized by two membership functions given by :-

(i) a truth membership function

$$t_A : U \rightarrow [0, 1], \quad \text{and}$$

(ii) a false membership function

$$f_A : U \rightarrow [0, 1]$$

where $t_A(u)$ is a lower bound of the grade of membership of u derived from the 'evidence for u', and $f_A(u)$ is a lower bound on the negation of u derived from the 'evidence against u', and $t_A(u) + f_A(u) \leq 1$. Thus the grade of membership of u in the vague set A is bounded by a subinterval $[t_A(u), 1- f_A(u)]$ of [0,1]. This indicates that if the actual grade of membership is $\mu(u)$, then $t_A(u) \leq \mu(u) \leq 1- f_A(u)$. The vague set A is written as $A = \{ < u, [t_A(u), f_A(u)] > : u \in U \}$, where the interval $[t_A(u), 1- f_A(u)]$ is called the vague value of u in A and is denoted by $V_A(u)$. For example, consider an universe U = { bad orientation, poor sanitation, cheap materials}. A vague set (VFS) A of U could be A = { < bad orientation, [.6,.2] >, < poor sanitation, [.2,.7] >., < cheap materials,[.3,.5]> }.

3. METHODOLOGY

For better understanding the methodology of composed fuzzy model of 'Vague Fuzzy EIA' and 'Fuzzy Decision' tool the following essential definitions are discussed below.

Definition 3.1 Attributes of the Assessment

Attributes are the fuzzy data collected for evaluation individually and the membership value of each either degree of truthness or degree of falseness lying within [1,0]. As for example if consider a project "Assessment of 'TIEV' of a Green Building (GB)", then some relevant attributes could be 'high reflective roof coating', 'bad orientation', 'poor sanitation', 'good indoor environmental quality', 'low constructional cost', 'good drainage system', 'heavy rainfall', 'high energy consumption', 'poor insulation', etc. out of many.

Definition 3.2 Universe of the Assessment

Collection of all attributes of the assessment is called the Universe of the Assessment.

Let $E = \{x_1, x_2……..., x_n\}$ be a finite discrete universe of attributes x_i, $i = 1, 2,…. , n$.

Definition 3.3 Mean Vague Fuzzy Set

Let E be an universe and X be an VS of E. The mean vague value of the VS X is also a fuzzy set Y of E whose membership function $\mu_{vs}(x)$ given by

$$\mu_{vs}(x) = \frac{t_A(x) + [1 - f_A(x)]}{2}$$

Definition 3.4 Total Environmental Impact Value (TEIV)

Let m be a mean fuzzy set of a finite set X and for each element $x \in X$, there is an associated weight $W_x \in R+$ (set of all non-negative real numbers) , then the TEIV of the fuzzy set m is the non-negative number given by $TEIV(m) = \sum [\mu(x_i)_m.W_i]$, $i = 1, 2, 3,……, n$. Naturally maximum TEIV will indicate logically more degree of certainty in support of that a building is more green.

Definition 3.5 Fuzzy Decision (FD)

As a human being all decision makers or engineers hesitates more or less on every evaluation activities due to limitation of knowledge or intellectual functionaries. The fuzzy decision (FD) is an appropriate tool to achieve the targeted goal where many constraints are clubbed with all possible decisions. In this paper cost of land and construction of a building are the two constraints to achieve the goal of most economical green building. To understand the function of FD an algorithm is presented below.

Algorithm of FD :

Logically in fuzzy decision, the membership value (μ) for the maximum favourable condition of a given goal or constraint is treated as 1 and for minimum it is 0.

Let us consider a group of options as O

Where, $O = \{ o_1, o_2, o_3, ……., o_L\} = \{ o_i \}$, for $i = 1, 2, 3, …, L$

Let a fuzzy set G describing goals associated with each option (o_i) such that

$$G = \{ \mu(g_1/o_1), \mu (g_2/o_2), \mu (g_3/o_3), ……., \mu (g_L/o_L)\} = \{ \boldsymbol{\mu(g_i/o_i)} \}, \quad \text{for } i = 1, 2, 3, …, L$$

Now if the two fuzzy sets C_1 and C_2 describing two constraints associated with each option (o_i) such that

$C_1 = \{ \mu_1(c_1/o_1), \mu_1(c_2/o_2), \mu_1(c_3/o_3), \ldots\ldots., \mu_1(c_L/o_L) \}$
$= \{ \boldsymbol{\mu_1(c_i/o_i)} \}$, for i = 1, 2, 3, …, L

And
$C_2 = \{ \mu_2(c_1/o_1), \mu_2(c_2/o_2), \mu_2(c_3/o_3), \ldots\ldots., \mu_2(c_L/o_L) \}$
$= \{ \boldsymbol{\mu_2(c_i/o_i)} \}$, for i = 1, 2, 3, …, L

Then the Fuzzy Decision (FD) will be given by FD = Max $\{D(o_i)\}$,

Where
$D(O_i)$ = [sub set-G ∩ sub set-C_1 ∩ subset-C_2]
= Min $\{\mu(g_i/o_i), \mu_1(c_i/o_i), \mu_2(c_i/o_i) \}$

Now to validate the fuzzy model, a case study is presented below.

4. CASE STUDY

Suppose a project "SELECTION OF MOST ECONOMICAL GREEN BUILDING OUT OF n-ALTERNATIVES" constructed in different cities but all buildings have the same plan, design and orientation. First we assess the TEIV of each green building independently and thereafter put the data in FD-model for taking decision which one is the actual most economical out of them. For this study we consider ten green buildings (GB) of ten different cities (CT) and five experts for each city for obtaining their views. In Fuzzy modeling, attributes plays a main keys for assessment of the job. For making simplicity in the methodology, we consider the following ten favourable attributes out of many for assessment:-

- x_1 = high reflective roof coating
- x_2 = good indoor environmental quality
- x_3 = good storm water management
- x_4 = good orientation
- x_5 = good sanitary fittings
- x_6 = good drainage system
- x_7 = good water quality and quantity
- x_8 = adequate natural light deep into the interior spaces
- x_9 = low energy consumption
- x_{10} = good habitable outdoor space

This data leads to the fuzzy set X of the universe E, where

$$E = \{ x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} \},$$

Now the job is to assign the values of these attributes for each green building (GB) by collecting views and perception from five experts independently. Suppose the data for the green building-GB_1 of city-CT_1 is presented in Table-1. The average perception of all experts is obviously the element of fuzzy subset $GB_1 \in E$, where , $\mathbf{GB_1}$ = {(x_1, .80, .15), (x_2, .85, .05), (x_3, .70, .10), (x_4, .70, .20),(x_5, .65, .25), (x_6, .60, .20), (x_7, .50,.30), (x_8, .40, .50), (x_9, .55, .10) , (x_{10}, .85, .10)}.

Table-1: Average Perceptions of Five Experts

Attributes ↓	Expert-1	Expert-2	Expert-3	Expert-4	Expert-5	Average Perception
x_1	(x_1,.75, .20)	(x_1,.90, .05)	(x_1,.75, .20)	(x_1,.85, .10)	(x_1,.75, .20)	(x_1,.80, .15)
x_2	(x_2,.85,.10)	(x_2,.88,.07)	(x_2,.82,.05)	(x_2,.87,.01)	(x_2,.83,.02)	(x_2, .85, .05)
x_3	(x_3,.65,.05)	(x_3,.70,.15)	(x_3,.80,.11)	(x_3,.75,.09)	(x_3,.60,.10)	(x_3, .70, .10)
x_4	(x_4,.60,.20)	(x_4,.80,.15)	(x_4,.64,.25)	(x_4,.76,.15)	(x_4,.70,.25)	(x_4, .70, .20)
x_5	(x_5,.66,.24)	(x_5,.71,.21)	(x_5,.67,.25)	(x_5,.62,.26)	(x_5,.59,.29)	(x_5, .65, .25)
x_6	(x_6,.63,.16)	(x_6,.54,.24)	(x_6,.60,.30)	(x_6,.57,.18)	(x_6,.66,.12)	(x_6, .60, .20)
x_7	(x_7,.50,.26)	(x_7,.46,.34)	(x_7,.53,.31)	(x_7,.50,.32)	(x_7,.51,.27)	(x_7, .50,.30)
x_8	(x_8,.41,.47)	(x_8,.40,.44)	(x_8,.39,.52)	(x_8,.39,.53)	(x_8,.41,.54)	(x_8, .40, .50)
x_9	(x_9,.52,.08)	(x_9,.58,.12)	(x_9,.51,.07)	(x_9,.57,.11)	(x_9,.57,.12)	(x_9, .55, .10)
x_{10}	(x_{10},.79,.16)	(x_{10},.80,.15)	(x_{10},.88,.07)	(x_{10},.86,.09)	(x_{10},.92,.03)	(x_{10}, .85,.10)

Now suppose weight of each attributes of set GB_1 are prefixed by the five experts of city-CT_1 like as for x_1 = 80, for x_2 = 90, for x_3 = 55, for x_4 = 40, for x_5 = 15, for x_6 = 35, for x_7 = 50, for x_8 = 70, for x_9 = 80, and for x_{10} = 95 respectively. Then the TEIV of GB_1 of city-CT_1, calculated by the definition-3.4 is given below (Table 2).

Table 2: TEIV of GB_1

Attribute	evidence for u t_A	evidence against u f_A	Vague value μ_{vs} (x)	weight of the attribute W_x	**TEIV of GB1**
x_1	.80	.15	.825	80	
x_2	.85	.05	.90	90	
x_3	.70	.10	.80	55	
x_4	.70	.20	.75	40	
x_5	.70	.25	.725	15	**459**
x_6	.60	.20	.70	35	
x_7	.50	.30	.60	50	

x_8	.40	.50	.45	70	
x_9	.55	.10	.725	80	
x_{10}	.85	.10	.875	95	

Similarly the average perceptions of experts and TEIVs of rest nine buildings are suppose as:

GB_2 = {(x_1, .75, .20), (x_2 , .80, .15), (x_3, .65, .20), (x_4 , .80,.10), (x_5, .75, 15), (x_6, .65 .20), (x_7, .55,.15), (x_8 , .55, .20), (x_9, .70, .20) , (x_{10} , .80, .15)}, and **TEIV = 386**

GB_3 = {(x_1, .70, .25), (x_2 , .70, .15), (x_3, .80,. 15), (x_4, .55, .30), (x_5, .70, .10), (x_6, .75, .10), (x_7, .80, .10), (x_8 , .50, .25), (x_9, .60, .30) , (x_{10} , .75, .10)} and **TEIV = 448**

GB_4 = {(x_1, .60, .30), (x_2 , .75, .20), (x_3, .60 ,.20), (x_4 , .65, .10), (x_5, .60, .25), (x_6, .65 .25), (x_7, .45, .50), (x_8 , .30, .60), (x_9, .50, .30) , (x_{10} , .50, .35)} and **TEIV = 357**

GB_5 = {(x_1, .65, .20), (x_2 , .80, .10), (x_3, .75, .10), (x_4 , .90, .05), (x_5, .65, .15), (x_6, .80, .15), (x_7, .60, .25), (x_8 , .50, .35), (x_9, .80, .10) , (x_{10} , .75, .10)} and **TEIV = 422**

GB_6 = {(x_1, .85, .10), (x_2 , .80, .10), (x_3, .70, .20), (x_4, .60, .20), (x_5, .65, .30), (x_6, .70 .10), (x_7, .65, .30), (x_8 , .80, .10), (x_9, .35, .55) , (x_{10} , .45, .30)} and **TEIV = 435**

GB_7 = {(x_1, .60, .30), (x_2, .75, .10), (x_3, 85, .10), (x_4 , .55, .20), (x_5, .85, .10), (x_6, .70, .20), (x_7, .50,. 40), (x_8, .60, .25), (x_9, .80, .15) , (x_{10} , .65, .15)} and **TEIV = 475**

GB_8 = {(x_1, .60, .20), (x_2 , .85, .10), (x_3, .45, .45), (x_4 , .70, .25), (x_5, .75, .20), (x_6, .70, .20), (x_7, .70, .25), (x_8 , .50, .30), (x_9, .65, .25) , (x_{10} , .70, .15)} and **TEIV = 365**

GB_9 = {(x_1, .65, .30), (x_2 , 75, .15), (x_3, .70, .10), (x_4 , .65,. 25), (x_5, .70, .15), (x_6 , .60, .35), (x_7, .55, .20), (x_8 , .40, .25), (x_9, .70, .20) , (x_{10} , .60, .30)} and **TEIV = 345**

GB_{10} = {(x_1, .70, .20), (x_2, .75, .15), (x_3, .85, .10), (x_4, .90, .05), (x_5, .65, .30), (x_6, .75, .15), (x_7, .75, .10), (x_8 , .50, .35), (x_9, .70, .10) , (x_{10} , .50, .30)} and **TEIV = 323**

Now the job is to follow the algorithm of Fuzzy Decision (FD) considering the data of TEIVs, cost of land and cost of construction and then finally come into conclusion which one is actually most economical Green Building (GB) out of 10 above options. All the data for the cost of land and construction of building (Table-3) are precise data and will not deviate by the expert's perception anyway.

Table-3 : Individual Data of Ten GBs

GB	TEIV	Cost of Construction (Rs. In lakhs)	Cost of Land (Rs. In lakhs)
GB_1	459	22	45
GB_2	386	34	30
GB_3	448	25	60
GB_4	357	38	90
GB_5	422	39	85
GB_6	435	45	55
GB_7	475	32	87
GB_8	365	48	69
GB_9	345	45	53
GB_{10}	323	36	90

For the fuzzy decision, the 'TEIV' will be the goal, i.e. **G** and if consider 'Cost of Construction' and 'Cost of Land' are the two constraints, i.e. **C_1** and **C_2**, then the fuzzy sets for each options will be as :

$$G = \mu(g_i/GB_i) = [\ 1.0/GB_1,\ 0.50/GB_2,\ 0.85/GB_3,\ 0.75/GB_4,\ 0.60/GB_5,\ 0.70/GB_6,\ 1.0/GB_7,\ 0.40/GB_8,\ 0.25/GB_9,\ 0.15/GB_{10}]$$

$$C_1 = \mu(C_1/GB_i) = [\ 1.0/GB_1,\ 0.65/GB_2,\ 0.90/GB_3,\ 0.50/GB_4,\ 0.45/GB_5,\ 0.30/GB_6,\ 0.8/GB_7,\ 0.20/GB_8,\ 0.30/GB_9,\ 0.55/GB_{10}]$$

$$C_2 = \mu(C_2/GB_i) = [\ 0.90/GB_1,\ 1.0/GB_2,\ 0.60/GB_3,\ 0.15/GB_4,\ 0.30/GB_5,\ 0.70/GB_6,\ 0.25/GB_7,\ 0.50/GB_8,\ 0.75/GB_9,\ 0.15/GB_{10}]$$

Therefore,

$$D(GB_i) = \mu(g/GB_i) \cap \mu(C_1/GB_i) \cap \mu(C_2/GB_i)$$

$$= [0.90/GB_1, 0.50/GB_2, 0.60/GB_3, 0.15/GB_4, 0.30/GB_5, 0.30/GB_6, 0.25/GB_7, 0.20/GB_8, 0.30/GB_9, 0.15/GB_{10}]$$

Then the fuzzy decision is given by

$$FD = \text{Max}\ \{D(GB_i)\} = 0.90/GB_1$$

Thus result reveals that the Green Building-GB_1 in the city of CT_1 is the best economical green building out of ten alternatives of different cities.

5. CONCLUSION

For selection of most economical green building, the uncertainty leads a major key role for the proper decision of an engineer due to rapid fluctuation of cost of land, materials, fuels and dramatically changes of environmental condition time to time and city to city. Thus to tackle the uncertainty involved in the decision of expert for selection of most economical as well as green, the composed model of Vague Fuzzy EIA and Fuzzy Decision can only give more precise result then any other tool so far available to an engineer or architecture at present day.

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