



APPROACH OF FUZZY LOGIC FOR EVALUATION OF GREEN BUILDING RATING SYSTEM

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Abstract: - For rating of a green building in India, the tool 'Green Rating for Integrated Habitat Assessment (GRIHA)' has a great role for evaluation process. Using the guidelines of GRIHA, overall rating of a green building is done based on the acquired points out of 104 after evaluation of a set of thirty four criterias by different experts independently[4]. Each criteria is well defined in terms of points and provision is kept to award the full point only after full satisfaction of the expert on the quality of works under that criteria. Naturally the membership value ($\mu(x)$) is considered as either 1 or 0 when the experts is either fully satisfied or not. So assessment in between 'acceptable and not acceptable'; 'best and poor'; 'efficient and not efficient'; 'more and less'; 'high and low'; 'good and bad' is not possible within [1,0] due to the involvement of uncertainty. Every expert hesitates more or less on every evaluation activity in between of all the above conditions because some part of his perception contributes to truthness and some part to falseness when he allots the points against different criterias. Thus uncertainty is an integral part of the accuracy of the assessments of each criterion which can be solved by the approach of fuzzy logic [6]. In this paper a flexible rating system is developed to address wide range of projects data with degree of certainty which is only the solution of the present day problem of GRIHA.

Keywords: fuzzy logic, GRIHA, rating system, uncertainty, weighted rating, etc.

1. Introduction:

India, like other developing countries, is going through a revolution in construction sector, which is the result of expanding population, growing urbanization and an increasing awareness about saving the environment. Building rating systems have been quite effective in raising awareness about energy efficient and green building design [1]. The site, design and operation of a building has to be such that the working and living environment is comfortable and the building has zero adverse effect on the environment. To facilitate the design, construction and operation of a green buildings, the tool 'GRIHA' developed by 'The Energy and Resources Institute (TERI)' and Ministry of New and Renewable Energy (MNRE) together has a great role in India for assessment of "greenness" of a green building in terms of rating like 1star, 2star, 3star, 4star & 5star[2,5]. There is a set of 34 criterias with differential weightage which gives total 104 points and after evaluation of each criteria by different experts, star rating will be awarded on the basis of total earned points out of 104, with minimum 50 points required for rating certification[4]. No points are granted for partial compliance i.e. if an evaluated criterion is satisfied then full point is awarded and if criteria is partially or not satisfied then 0 point is awarded. There is no provision of intermediate points in between for corresponding to partially satisfied or partially acceptable cases. If the membership value ($\mu(x)$) of satisfaction is considered as 1 then for not satisfaction it will be 0, nothing will be in between 1 and 0. Whereas it is seldom possible that a criteria is fully satisfied but can be complied to a certain degree of satisfaction for which the membership value ($\mu(x)$) of satisfaction can be any value within [1,0] due to involvement of uncertainty in between two zones of satisfaction and not-satisfaction of the expert. Thus it is very difficult to make genuine assessment based only on full points allotted logic. Instead we will have to consider all degree of perceptions of expert within [1,0].

There are total 34 criterias in GRIHA for rating of greenness of a building and for all cases evaluation is done by human being where there is certainly a limitation of knowledge or intellectual functionaries. The statistical observations or data so obtained for rating of a green building against 34 criterias are not always crisp or precise. Most of the data are non-numeric or unreliable statistical data rather linguistic and hedges viz. "good site", "very good water quality", "less noisy", "less landscape", "well designed", "more renewable energy", "highly acceptable", etc. to list a few only out of infinity. Such types of imprecise data are fuzzy in nature [3,6]. Evaluation of many criteria here is not always possible with numerical valued description for which basis we awarded the full point as per GRIHA. All the out put evaluation results of criterias are 100% based on the satisfaction level and the perception level of the experts which can never be same for all the situations, indoor as well as outdoor environment. Consequently it is ideal to adopt a proper mathematical tool to do a proper and genuine judgment and rating of a green building and certainly fuzzy logic is the most suitable for the purpose. Because of this obvious reason we adopt fuzzy logic in the present work.

2. Methodology

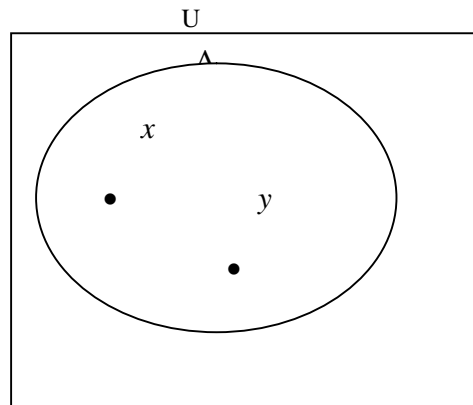
Now we propose a methodology of fuzzy assessment for rating of a green building based on criterias by GRIHA. For better understanding the proposed fuzzy based methodology, few useful preliminaries are discussed below.

2.1 Crisp Set

A crisp set can be described by a characteristic function or discrimination function by which individuals from the universal set X are determined to be either members or nonmembers of a set. Suppose for a given set A , this function assign a value $\mu_A(x)$ to every $x \in X$ such that

$$\mu_A(x) = 1 \text{ iff } x \in A, \text{ and } \mu_A(x) = 0 \text{ iff } x \notin A$$

In crisp set theory, a very precise boundary is there to determine whether an element belongs to a set or not. Accordingly the membership value in favour of the truthness of belongingness of an element/attribute is considered as 1 or 0. For example, if A is the sub set of universal set U membership values of the elements of the universe with respect to it's subset are $\mu_A(x) = 1$, $\mu_A(y) = 1$, and $\mu_A(z) = 0$.



(Fig-1: Crisp Set A and elements x , y and z of Universal Set U)

2.2 Fuzzy Set [6]

This crisp characteristic function can now be generalized such that the values assigned to the elements of the universal set fall within a specified range $[0,1]$ and indicate the membership grade of these elements in the set in question. There is no clear boundary in between set A and it's universal set U and thus we can not draw it. Such a function is called membership function and the set defined as fuzzy set. The membership function for fuzzy sets can take any value from the closed interval $[0,1]$ instead of either 0 or 1 like crisp set[3]. Fuzzy set A is defined as the set of ordered pairs $A = \{ (x_1, \mu_A(x_1)), (x_2, \mu_A(x_2)), \dots, (x_n, \mu_A(x_n)) \}$, where $\mu_A(x)$ is the grade of membership of element x in set A . Greater the $\mu_A(x)$, greater is the truthness of the statement that element x belongs to set A [6].

Example: Let us consider a set $X = \{2, 5, 9, 18, 21, 25\}$, whose elements denote the number of vehicles waiting in line at a signal. Set B consists of the fuzzy set "small number of vehicles in line." Fuzzy set B can be shown as: $B = \{ (2, 0.95), (5, 0.55), (9, 0.20), (18, 0.10), (21, 0.05), (25, 0.01) \}$. The grades of membership 0.95, 0.55, ..., 0.01 are subjectively determined and indicate the "strength" of membership of individual elements in fuzzy set B .

2.3 Attribute of the Assessment [3]

The assessment is done by collecting information or values for certain attributes which are called the attributes of the assessment. For example, consider a project of "Rating of Green Building", for which some relevant attributes could be "good site selection", "less building water use", "more resource recovery" etc.

2.4 Universe of the Assessment [3]

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

2.5 Total Weighted Rating of a Fuzzy Set

Let μ be a fuzzy set of a finite set X . Suppose that to each element $x \in X$, there is an associated weight $W_x \in R^+$ (set of all non-negative real numbers).



Then the 'weighted rating' of the fuzzy set μ is the non-negative number $a(\mu)$ given by

$$a(\mu) = \sum_{i=1}^n \{ \mu(x_i) W_{xi} \}$$

2.6 Grading of Fuzzy Assessment Output

In order to achieve the GRIHA certification a project must achieve minimum 50 points out of 100. Depending upon the value of $a(\mu)$, the grading of overall output for award the GRIHA certificate could be temporarily proposed as below :-

| | |
|-----------------------------------|-----------------------------|
| grade A = 5 Star rated building , | if $90 < a(\mu) \leq 100$ |
| grade B = 4 Star rated building , | if $80 < a(\mu) \leq 90$ |
| grade C = 3 Star rated building , | if $70 < a(\mu) \leq 80$ |
| grade D = 2 Star rated building , | if $60 < a(\mu) \leq 70$ |
| grade E = 1 Star rated building , | if $50 \leq a(\mu) \leq 60$ |

In next section we present the methodology of assessment of GRIHA rating scale by a case study.

3. Case Study

Consider a project 'ASSESSMENT OF RATING OF A GREEN BUILDING'. To assess the rating of green building, we consider all criterias of GRIHA as attributes (x_i) of proposed methodology except criteria no-32 & 34 as both have no direct influence in the overall rating of the building. We also consider all the points of GRIHA assigned against each criterion as weightage (W_i) of that particular attribute. Considering favourable aspects of green building, suppose the 32 attributes with their weightage are:-

- x_1 = good site selection ($W_1=1$)
- x_2 = well preserved and protected landscape during construction ($W_2=5$)
- x_3 = good soil conservation (post construction) ($W_3=4$)
- x_4 = well designed to include existing site features ($W_4=2$)
- x_5 = good reduction in hard paving on site($W_5=2$)
- x_6 = good enhanced outdoor lighting system efficiency ($W_6=3$)
- x_7 = well planned and optimised utilities circulation efficiency($W_7=3$)
- x_8 = good provision of sanitation/safety facilities for construction workers ($W_8=2$)
- x_9 = less air pollution during construction ($W_9=2$)
- x_{10} = less landscape water requirement($W_{10}=3$)
- x_{11} = less building water use($W_{11}=2$)
- x_{12} = less wastage of water during construction($W_{12}=1$)
- x_{13} = good building design to reduce conventional energy demand($W_{13}=6$)
- x_{14} = good energy performance of building within specified comfort($W_{14}=12$)
- x_{15} = good use of fly ash in building structure($W_{15}=6$)
- x_{16} = good use of efficient construction technology ($W_{16}=4$)
- x_{17} = less use of low-energy material in interiors($W_{17}=4$)
- x_{18} = more renewable energy utilization($W_{18}=5$)
- x_{19} = more renewable energy based hot water system($W_{19}=3$)
- x_{20} = good waste water treatment process($W_{20}=2$)
- x_{21} = good water re-cycle and re-use (including rainwater) ($W_{21}=5$)
- x_{22} = less waste during construction($W_{22}=2$)
- x_{23} = good waste segregation($W_{23}=2$)
- x_{24} = good storage and disposal of waste($W_{24}=2$)
- x_{25} = more resource recovery from waste($W_{25}=2$)
- x_{26} = less use of low VOC paints / adhesive/sealants($W_{26}=4$)
- x_{27} = less ozone depleting substances($W_{27}=3$)
- x_{28} = good water quality($W_{28}=2$)
- x_{29} = high acceptable outdoor and indoor noise level($W_{29}=2$)
- x_{30} = good tobacco and smoke control($W_{30}=1$)
- x_{31} = high universal accessibility($W_{31}=1$)
- x_{32} = good operations and maintenance protocol ($W_{32}=2$)



Naturally, all independent expert's views for individual attribute will lead to a fuzzy set of the universe U, where $U = \{x_1, x_2, x_3, x_4, x_5, \dots, x_{32}\}$.

Now the job is to assign values to these attributes. This can be done either by direct observation or by collecting views from all the stakeholders. Let us suppose that the data collected for an attribute x_i reveals that more or less 70 % are in support of the truthness of the attribute and the rest 30% are in support of falseness then the membership value of fuzzy set will be $\mu_A(x_i) = 0.7$. Suppose the membership values of each attribute judged by different experts are as below:

| attribute | in support of truthness $\mu(x)$ | in support of falseness = $(1-\mu(x))$ | weight of the attribute W_x | weighted Rating |
|--|----------------------------------|--|-------------------------------|-----------------|
| x_1 | .75 | .25 | 1 | 0.75 |
| x_2 | .65 | .35 | 5 | 3.25 |
| x_3 | .5 | .5 | 4 | 2.0 |
| x_4 | .6 | .4 | 2 | 1.2 |
| x_5 | .8 | .2 | 2 | 1.6 |
| x_6 | .7 | .3 | 3 | 2.1 |
| x_7 | .9 | .1 | 3 | 2.7 |
| x_8 | .45 | .55 | 2 | 0.9 |
| x_9 | .9 | .1 | 2 | 1.8 |
| x_{10} | .75 | .25 | 3 | 2.25 |
| x_{11} | .55 | .45 | 2 | 1.1 |
| x_{12} | .85 | .15 | 1 | 0.85 |
| x_{13} | .45 | .55 | 6 | 2.7 |
| x_{14} | .55 | .45 | 12 | 6.6 |
| x_{15} | .85 | .15 | 6 | 5.1 |
| x_{16} | .4 | .6 | 4 | 1.6 |
| x_{17} | .55 | .45 | 4 | 2.2 |
| x_{18} | .45 | .55 | 5 | 2.25 |
| x_{19} | .6 | .4 | 3 | 1.8 |
| x_{20} | .75 | .25 | 2 | 1.5 |
| x_{21} | .85 | .15 | 5 | 4.25 |
| x_{22} | .5 | .5 | 2 | 1 |
| x_{23} | .6 | .4 | 2 | 1.2 |
| x_{24} | .85 | .15 | 2 | 1.7 |
| x_{25} | .8 | .2 | 2 | 1.6 |
| x_{26} | .9 | .1 | 4 | 3.6 |
| x_{27} | .45 | .55 | 3 | 1.35 |
| x_{28} | .9 | .1 | 2 | 1.8 |
| x_{29} | .75 | .25 | 2 | 1.5 |
| x_{30} | .85 | .15 | 1 | 0.85 |
| x_{31} | .5 | .5 | 1 | 0.5 |
| x_{32} | .6 | .4 | 2 | 1.2 |
| Total Weighted Rating (a(μ)) = | | | | 64.8 |

From the result of fuzzy assessment, the 'Total Weighted Rating (a(μ))' value is = **64.8** and thus the grade is to be awarded as "D"

Result: The building is **2 Star** rated green building.



4. Conclusion

GRIHA rates the greenness of a building by awarding points based on a set of criteria evaluated by experts. There is no scope for fluctuations of experts' perceptions or insufficient and unreliable statistical data, while taking decision towards evaluation of any criteria. Every expert as a human being will feel uncomfortable to assess a criteria by linguistic variables like good, bad, best, low, high etc for which he has to award points allocated against it.

The proposed fuzzy model based on GRIHA criterias has tremendous powers to minimize the uncertainty that arises due to experts' perceptions. Even the most minimal compliance of criteria can be accounted for in the Fuzzy analysis making the rating process more precise. The Green Rating thus obtained in the overall output result has more degree of certainty than from the present guidelines of GRIHA.

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