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Global Weights of Pre and Post Occupancy Parameters for Residential Green Buildings in Indian Context

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Abstract

'Green Building' and its 'Assessment Schemes' are the key to achieve the sustainable growth of the urban zone. An attempt is made to develop Global Weights (λi) of various parameters for the assessment of green Buildings. Analytic Hierarchy Process (AHP) is used to derive Sustainability Global Weights (λi) for all contributing parameters: Environmental, Social, Economical and Cultural. Consultants from various regions of India were asked to give their responses on AHP based questionnaire. Based on 72 valid responses from consultants, Global Weights of parameters are derived by Geometric Mean Method (GMM) along with AIP (Aggregation of Individual Priorities) approach. Consultants have ranked site selection, regional priority, Rapid Renewable Materials, as most crucial parameters in pre occupancy phase and Segregation and Disposal of waste, functionality and indoor air quality as most crucial parameters in post occupancy phase. Findings of this paper can be helpful to designers and developers to achieve real sustainable development in developing country like India.
Keyword- Analytic Hierarchy Process, Geometric Mean Method, Global Weights, Pre-Occupancy and Post-Occupancy

I. INTRODUCTION

The current decade has witnessed a growth of concern among all stakeholders to move toward sustainable development (SD). Collaborative effort is needed from all concerned with the development. Day-by-day sustainable urban development (SUD) is becoming more and more important with the exploration of urbanization in all countries. Achievement is only possible with collective effort by every industry in the country. In developing countries like India, a rising population, increasing standards of living, and rapid urbanization result in an increase in building construction activities. Buildings not only use resources, such as energy and raw materials, but they also generate waste and potentially harmful atmospheric emissions (Lee and Chan 2008). The building industry is one of the major contributors, along with policymakers, legal systems, and the economics of the urban area for SUD because of major involvement in future development of urban sectors. Some facts regarding contribution of buildings for SUD are as follows:

- Buildings account for almost 40% of the world’s energy requirements. In Canada, the U.K., and the United States, energy consumption by buildings is found to be between 30 and 50% of the country’s total demand (Erlandsson and Borg 2003; Nelms et al. 2005).
- Around 30% of the power consumed in residential, residential, and public structures can be conserved through better insulation, well-regulated ventilation and air conditioning systems, and more efficient heating technologies.
- The building industry constitutes approximately 44% of the society’s total material use (Erlandsson and Borg 2003).
- Buildings create two kinds of effects on the environment: consumption of natural resources and contribution to environmental deterioration (Lee and Tiong 2007). Buildings are found to be contributing between 25 and 48% of the sulfur dioxide emissions in the U.K. and United States (Dewick and Miozzo 2002; Kibert 2005). Thus, buildings are the single largest source of terrestrial and atmospheric pollution.

Therefore, the construction industry is adopting green or sustainable designs to attain higher environmental performance, along with functional and social sustainability achievement goals. A green building (GB) could be described as a subset of SD, which requires a continuous process of balancing of environmental, social, and economic systems in order to sustain for future generations (Alnaser et al. 2008). GB as assessment methods have emerged in recent years as a means to evaluate the performance of buildings across a broad range of sustainable considerations (Du Plessis 1999). These assessment methods provide a methodology for scoring or rating a building’s environmental effects, resource consumption, and health impacts. Such assessment methods will help the architects, engineers, planners, and developers understand the principles of GB design and follow a methodical approach.

The Indian construction industry is one of the leading growing sectors, which contribute to 10% of India’s gross domestic product. The Indian construction sector is growing at a rate of 9.2%, while the world average is 5.5%. The construction sector is likely to record higher growth in the coming years. Therefore, the Indian construction sector should apply strategies to reduce the

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environmental footprint of the buildings to be constructed in the coming years. SBTool 2007 (SBC 08 2007) is an international assessment tool that covers parameters from all directions: environmental, social, economic, and cultural. SBTool 2007 (SBC 08 2007) is an outcome of brainstorming of technocrats from 20 developing countries under the organization International Initiative for Sustainable Built Environment (http://www.iisbe.org). It is collaborative effort to develop a common tool for assessment of GB. Current Indian assessment tools like Green Rating for Integrated Habitat Assessment (GRIHA) and Leadership in Energy and Environment Design (LEED INDIA) (http://www. igbc.in/site/igbc/testigbc.jsp?desc=22905andevent=22869) do not cover all above parameters. Relative importance of the criteria in the form of numeric weighting is not adopted in both Indian systems. The objective of this paper is to develop the global weight (GW) of a broad range of contributing parameters for GB assessment, with the help of assessing structure of SBTool 2007 (SBC 08 2007). GW is the term used for lower-level parameter's importance with reference to GB assessment.

II. WEIGHTING OF CRITERIA

Weighting of criteria is the term used for its relative importance with reference to GB assessment. Criteria for GB assessment are divided into different levels of hierarchy as issue-category-parameters. Developing a weighting system of parameters is considered a necessary stage for developing building assessment tools (Ali and Al Nsairat 2008). Weighting is the heart of all assessment schemes, because it dominates the overall performance score of the building being assessed (Lee et al. 2002). The main concern is the absence of an agreed theoretical and no subjective basis for deriving weighting factors (Cole 1998). Local weight (LW) is the term used for the relative importance of a parameter within its group. Within individual group of the category's parameters, the total of the LW will be 1. If the GW of all parameters in the given hierarchy is summed up, then it will be 1. Here, the current structure of the SBTool 2007 (SBC 08 2007) is taken as a base. Todd et al. (2001) have noted that the SBTool 2007 (SBC 08 2007) can be used as a reference and basis for developing a domestic assessment method for GBs. The SBTool 2007 (SBC 08 2007) has a total of 119 low-level parameters. Currently, India has two assessment tools for green building: LEED INDIA and GRIHA (GRIHA). Here, LEED INDIA, GRIHA (GRIHA), and the SBTool 2007 (SBC 08 2007) are studied together; and according to Indian conditions, criteria of the SBTool 2007 (SBC 08 2007) are reduced to 100 by adding and deleting the criteria. This has been done by taking the opinions of experts who are involved in green construction in India. Some of the criteria of the SBTool 2007 (SBC 08 2007), which are removed from the hierarchy, are as follows: use of integrated design process, recycling of solid waste, reuse of sludge, maintenance of wildlife corridors, electrical peak demand for facility operations, use of durable materials, use of bio based products, emissions leading to photo oxidants, liquid effluents from facility operations, untreated storm water retained on site, and protection of materials during construction. A hierarchical framework is prepared for the development of the GW (li) of all parameters, which contributes to GB assessment. In the absence of scientifically based weights, some organizations use consensus-based weighting. In this approach, group of experts or users rank various elements, such as environmental issues, in terms of their relative importance or assign points to these elements (Todd et al. 2001). These weighting coefficients can be derived by questionnaire surveys to obtain options from the users of the system, such as designers, building owners and operators, and related officials. Most environmental building assessment methods are developed for general use and do not allow for national or regional variations (Lee et al. 2002). This means that assessment systems are applicable to any region of the country for building assessment without any change in assessment methodology. Every country must have certain regional differences, such as environmental, geographical, and resource availability, which are not considered in the current tools. The two critical issues within the debate are the basis for deriving weightings and the manner in which the weighting process affects the interpretation of the aggregated results of the building performance (Aull-Hyde 2006). The analytic hierarchy process (AHP) is used to develop GW, and then ranking is given to all contributing parameters according to their GW. A survey questionnaire was circulated among consultants who are involved in the design of such buildings.

III. HIERARCHICAL FRAMEWORK FOR GREEN BUILDING ASSESSMENT

GB covers broad aspects such as environmental, social, economic, and cultural systems. Based on the international assessment tool SBTool 2007 (SBC 08 2007), a hierarchical framework is developed, as shown in Fig. 1. The goal of GB is divided into nine major issues:

- Pre occupancy: architectural aspects, construction aspects;
- Post occupancy: occupancy, building maintenance;
- Architectural aspects: sustainable site, project planning, innovation in design;
- Construction aspects: materials resource and reuse, economical and social aspects, environmental loadings;
- Occupancy: indoor environmental quality, health and wellbeing , waste management;
- Building maintenance: security and safety, building operation and maintenance, flexibility and adaptability;

The AHP model is formulated consisting of issues, categories, and parameters. The topmost level is the total weighted result of the modified SBTool 2007 (SBC 08 2007), and the lowest level is the parameters.

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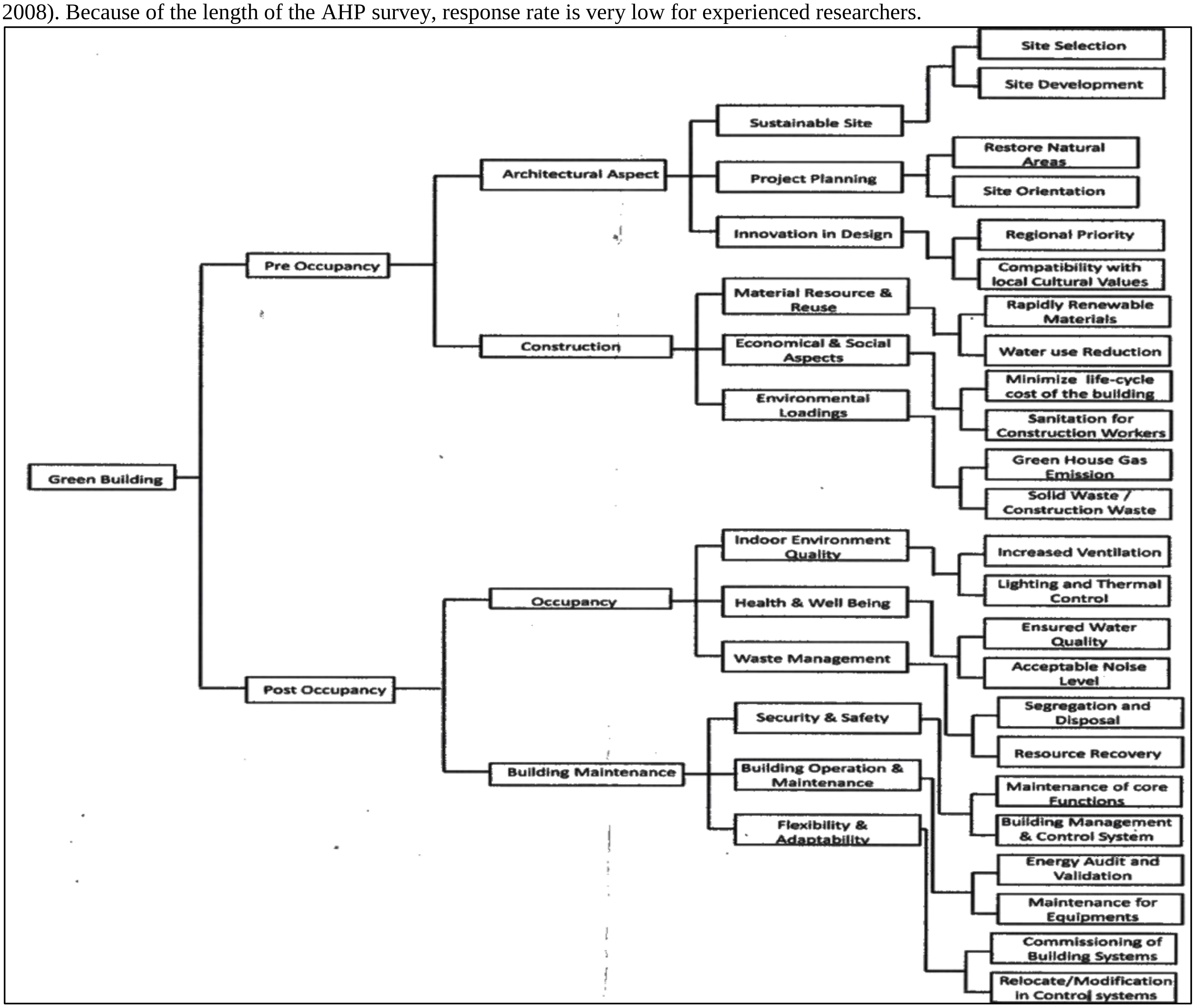
IV. ANALYTIC HIERARCHY PROCESS APPROACH

The AHP is one of the multi-criteria decision-making (MCDM) methods. AHP gives excellent performance in dealing with in-dependent criteria and local problems involving both qualitative and quantitative issues (Alwaer and Clements-Croome 2010). AHP is a reliable tool to facilitate systematic and logical decision-making processes and determine the significance of a set of criteria and sub criteria. It is widely applied to construction fields, such as re-source allocation, project design, planning for urban development, maintenance management, and policy evaluation (Cook et al. 1984). The AHP should be carried out in the following steps:

- Set out the decision problem in a hierarchical pattern;
- Determine the respondents because the AHP relies on experts' judgments;
- Questionnaire distribution for one-to-one comparison on a 1–9 scale by each respondent;
- Construct a reciprocal matrix from pairwise comparison for each respondent;
- Calculate the priority weights of each criterion based on Saaty's eigenvector method (EM);
- Measure the consistency ratio (CR)—this is done to decide whether experts are consistent in giving their feedback or not.
- If the CR value is more than 0.10, then experts have given their judgments arbitrarily and either it is to be rejected or done again;
- Aggregate priority weights of all respondents to derive aggregated LW by the geometric mean method (GMM); and GW derivation of each parameter based on their LWs at each hierarchical level.

Pairwise comparison is an important step in the AHP, which is to be completed by experts. However, the AHP is widely criticized for being such a tedious process, especially when a large number of criteria or alternatives are involved (Lee and Chan 2008). Because of the length of the AHP survey, response rate is very low for experienced researchers.



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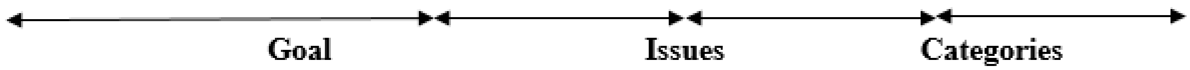

Criteria

Fig. 1: Residential Green building assessment framework – structure

V. DATA COLLECTION AND ANALYSIS

AHP-based survey questionnaires were circulated to consultants and architects involved with design work of green and GB in India. This study sent 80 copies to consultants who were experts in the field. These consultants were leaders in their field of green construction, and hence their voice holds great importance as the view of the whole fraternity of architects and consultants. One of the limitations of AHP-based surveys is the length of the questionnaire, which is a result of its inbuilt rule of one-to-one comparison of criteria at each level to derive priority weights. A total of 37 responses were received from consultants from different regions of India. Their responses were processed as per AHP procedure, with the use of Microsoft Excel software. Priority vector of each matrix was generated by the EM, because it is the only method that deals well with inconsistency. The preferences given by each individual expert have to be aggregated to obtain a single weight for each parameter. The GMM is a commonly used method in the AHP to aggregate judgments of individuals within a group (Ding 2008). The geometric mean is less affected by the extreme values than the arithmetic mean and is also more effective because the authors are dealing with ratios. Responses beyond the CR value of the acceptance level were rejected from the AHP calculations. For group decision making, the AHP considers two different approaches: aggregation of individual judgments and the aggregation of individual priorities (AIPs). In this study, AIPs is used. A set of global priority weights can be determined for each of the parameters by multiplying the LW of the parameters by the weights of all the parent nodes above it. The priority GW of each parameter is derived by Eq. (1) (Pavlikakis and Tsihrintzis 2003)

$$G.W.\ CR\ i = L.W.I\ i \times L.W.Ci \times L.W.\ CRi \qquad (1)$$

Here, i = 1, 2, 3….n = Issue, Category and Criteria at each level
G.W. CR i = Global weight of ith criterion,
L.W.I i = Local weight of ith issue
L.W.Ci = Local weight of ith category,
L.W. CRi = Local weight of ith criterion

The priority GW of each parameter is given in Table 1. GW is the importance of criteria contributing for GB. The higher the GW means the higher the importance of criteria for a building to be considered as a sustainable one. According to the GW value of all parameters, crucial parameters could be listed.

VI. RESULT AND DISCUSSION

GW and the ranking of parameters indicates the opinion from the experts on the practical aspects of the recent period and local situations. Consultants (architects dealing with design preparations of building projects) from India who are dealing with green designs for the building projects are giving more importance to energy and water-related parameters compared with other issues, such as environmental loading and indoor air quality.

Sr no	*No*	*Criteria*	*Global Weight*
		PRE-OCCUPANCY	
A		*SUSTAINABLE SITE*	
A.1		*SITE SELECTION*	
1	*A.1.1*	*Proximity of site to commercial and cultural facilities*	*0.0033858*
2	*A.1.2*	*Proximity of site to public recreation areas and facilities*	*0.0029875*
3	*A.1.3*	*Vulnerability of land to flooding - height of building plinth from flood level*	*0.0046355*
A.2		*SITE DEVELOPMENT*	
4	*A.2.1*	*Pre-development agricultural value of land*	*0.0051152*
5	*A.2.2*	*Brownfield redevelopment- sub surface contamination due to old building*	*0.0046718*
6	*A.2.3*	*Pre-development ecological value or sensitivity of land - flora and fauna of site land*	*0.0049046*
A		*TOTAL GOLBAL WEIGHT*	*0.0257004*
B		*PROJECT PLANNING*	
B.1		*RESTORE NATURAL AREAS*	

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7	B.1.1	Potential environmental impact of development or re-development	0.0054719
8	B.1.2	Protect or restore habitat - Conserve existing natural areas.	0.0066837
9	B.1.3	Provision of surface water management system	0.0077615
B.2	SITE ORIENTATION		
10	B.2.1	Availability of potable water treatment system / Ensure water quality	0.0074275
11	B.2.2	Availability of split grey/ potable water system	0.0063387
12	B.2.3	Efficient utility utilization and optimized on site circulation during construction	0.0057634
B		TOTAL GOLBAL WEIGHT	0.0394469
C	INNOVATION IN DESIGN		
C.1	REGIONAL PRIORITY		
13	C.1.1	Development density - Ratio of total built-up area to permissible built-up area	0.0043211
14	C.1.2	Development footprint - Open space in plot compared to local zone requirement	0.0051819
15	C.1.3	Provision of project green space	0.0067098
C.2	COMPATIBILITY WITH LOCAL CULTURAL VALUES		
16	C.2.1	Relationship of design with existing streetscapes	0.0240658
17	C.2.2	Compatibility of urban design with local cultural values	0.0281042
18	C.2.3	Maintenance of heritage value of existing building	0.0297710
C		TOTAL GOLBAL WEIGHT	0.0981541
D	MATERIALS AND RESOURCES		
D.1	RAPIDALLY RENEWABLE MATERIALS		
19	D.1.1	Reuse of existing structure	0.0256184
20	D.1.2	Use of recycled materials from off-site sources	0.0254244
21	D.1.3	Use of materials that are locally produced	0.0248237
D.2	WATER USE REDUCTION		
22	D.2.1	RAINWATER: Retention of rainwater for later re-use on site	0.0334413
23	D.2.2	Efficient water use during construction	0.0322476
24	D.2.3	Water use reduction	0.0547147
D		TOTAL GOLBAL WEIGHT	0.1962704
E	SOCIAL and ECONOMICAL ASPECTS		
E.1	SOCIAL ASPECTS		
25	E.1.1	Minimization of construction accidents	0.0098954
26	E.1.2	Access for physically handicapped persons	0.0090106
27	E.1.3	Providing minimum level of sanitation facilities for construction workers during the construction of building	0.0091308
E.2	ECONOMICAL ASPECTS		
28	E.2.1	Minimization of life-cycle cost of the building	0.0273003
29	E.2.2	Minimization of construction cost of the building	0.0089991
E		TOTAL GLOBAL WEIGHT	0.0643364
F	ENVIRONMENTAL LOADINGS		
F.1	GREENHOUSE GAS EMISSIONS		
30	F.1.1	Reduced CO2 emissions during construction	0.0215529
31	F.1.2	Annual GHG emissions from energy used for facility operations	0.0290396

32	*F.1.3*	*Emissions of ozone depleting substances by building operations*	*0.0110964*
F.2	*SOLID WASTE*		
33	*F.3.1*	*Solid waste from construction operations*	*0.0075713*
34	*F.3.2*	*Solid waste from building operations- storage, sorting, re-use and disposal scheme implementation*	*0.0138010*
F		*TOTAL GLOBAL WEIGHT*	*0.0830613*
		TOTAL GLOBAL WEIGHTS - A to F ISSUES	*0.506969*
POST OCCUPANCY			
G	*INDOOR ENVIRONMENT QUALITY*		
G.1	*INCREASED VANTILATION*		
1	*G.1.1*	*Effectiveness of ventilation in naturally ventilated occupancies*	*0.0260229*
2	*G.1.2*	*Air quality and ventilation in mechanically ventilated occupancies*	*0.0121398*
G.2	*LIGHTNING AND THERMAL CONTROL*		
3	*G.2.1*	*Day lighting in primary occupancy areas*	*0.0209266*
4	*G.2.2*	*Air temperature in naturally ventilated spaces*	*0.0224297*
5	*G.2.3*	*Illumination levels and quality of lighting*	*0.0074248*
G		*TOTAL GLOBAL WEIGHT*	*0.0889440*
H	*HEALTH and WELL BEING*		
H.1	*INDOOR AIR QUALITY*		
6	*H.1.1*	*Use of low-emitting interior finishing materials*	*0.0053802*
7	*H.1.2*	*Minimize exposure of building occupants to chemical pollutants*	*0.0065827*
8	*H.1.3*	*CO2 monitoring system for indoor air quality*	*0.0068847*
H.2	*ACCEPTABLE NOISE LEVEL*		
9	*H.2.1*	*Noise attenuation through the exterior envelope of the building*	*0.0049444*
10	*H.2.2*	*Noise attenuation between primary occupancy areas*	*0.0047364*
11	*H.2.3*	*Acoustic performance within primary occupancy areas*	*0.0048263*
H		*TOTAL GLOBAL WEIGHT*	*0.033355*
I	*WASTE MANAGEMENT*		
I.1	*SEGREGATION and DISPOSAL*		
12	*I.1.1*	*Waste collection method*	*0.0054445*
13	*I.1.2*	*Waste segregation: Dry and Wet waste*	*0.005922*
14	*I.1.3*	*Adopted waste disposal methods within occupancy premises*	*0.0252256*
I.2	*RESOURCE RECOVERY*		
15	*I.2.1*	*Design for disassembly, re-use or recycling the structure in the future*	*0.0519936*
16	*I.2.2*	*Use of rapidly renewable materials in place of long-cycle renewable materials*	*0.072742*
17	*I.2.3*	*Use of certified wood for wood-based products for environmentally responsible forest management*	*0.012814*
I		*TOTAL GLOBAL WEIGHT*	*0.1741426*
J	*SECURITY and SAFETY*		
J.1	*MAINTANANCE OF CORE FUNCTIONS*		
18	*J.1.1*	*Maintenance of core building functions during power failures*	*0.0347946*
19	*J.1.2*	*Capability for partial operation of building management control systems*	*0.0053270*

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20	J.1.3	Provision and operation of building management control system	0.0061513
J.2	BUILDING MAINTENANCE and CONTROL SYSTEMS		
21	J.2.1	Development and implementation of maintenance management plan during operation of the building	0.0193763
22	J.2.2	Retention of as-built drawings and documentation	0.0083177
23	J.2.3	Performance incentives in lease or sales agreements	0.0075755
J		TOTAL GLOBAL WEIGHT	0.0815426
K	BUILDING OPERATION and MAINTENANCE		
K.1	FUNCTIONALITY		
24	K.1.1	Spatial efficiency - Ratio of directly functional net area to total net area	0.0087183
25	K.1.2	Volumetric efficiency - Ratio of directly functional net volume to total net volume	0.0094497
K.2	MAINTENANCE FOR EQUIPMENTS		
26	K.2.1	Provision for alternate equipments	0.0097183
27	K.2.2	Provision of power backup for equipments	0.0075762
28	K.2.3	Periodically maintenance action plan for equipments	0.0053286
K		TOTAL GLOBAL WEIGHT	0.0407914
L	FLEXIBILITY and ADAPTABILITY		
L.1	COMMISIONIMG OF BUILDING SYSTEM		
29	L.1.1	Adaptability constraints imposed by the structure	0.0075960
30	L.1.2	Adaptability constraints imposed by floor-to-floor heights	0.0241149
31	L.1.3	Adaptability constraints imposed by building envelope and technical systems	0.0055216
L.2	MODIFICATION IN CONTROL SYSTEM		
32	L.2.1	Commissioning of building system	0.0222699
33	L.2.2	Adaptability to future changes in type of energy supply	0.0071428
34	L.2.3	Ability to modify/ relocate building management control systems during use in future	0.0126201
L		TOTAL GLOBAL WEIGHT	0.0792656
		TOTAL GLOBAL WEIGHTS - G to L ISSUES	0.498041
		TOTAL GLOBAL WEIGHTS - A to L ISSUES	1.000011

Table 1: Criteria Global Weights

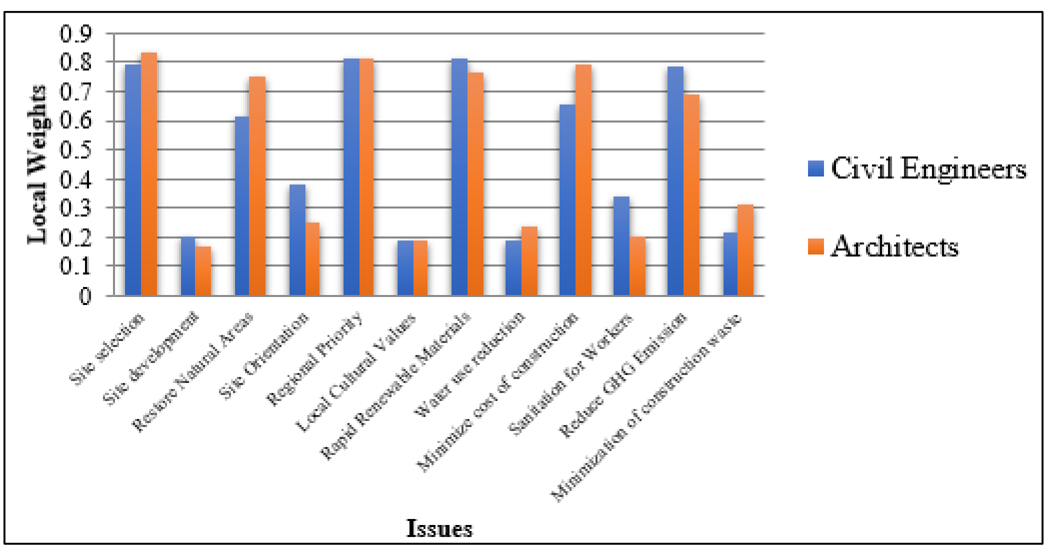

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Fig. 2: Weights of GB issues: All datasets comparison

Figure 2 shows a comparison of 12 issues for Residential Green Building for all datasets. Site Selection is the first prioritized issue by Civil Engineers and Architects. Sustainable site score highest weightage of 62 % amongst all issues. Material resource and reuse scores highest weightage of 57 % amongst all issues. Indoor environment quality scores highest weightage of 52 % amongst all issues. The view of respondents reflects the current national scenario, as India is facing for sustainable site and it is highly needed for residential green building. Material Resource and reuse is another burning issue in most of the regions and hence very rightly respondents' have given it second rank. Then they gave priority to environmental impact created by building construction activities. Urban dwellers have given first priority to indoor environmental quality (52%), security and safety (41%), building operation and maintenance (32 %), flexibility and adaptability (27%), waste management (27%) and health and wellbeing (23%).

VII. Conclusions And Recommendations

This paper presents a methodology to work out GW and ranking of parameters for the assessment of GBs in Indian context. A numeric number in the form of GW represents the relative importance of parameters, with reference to GB assessment. GW for a set of 100 parameters is generated with an MCDM approach. An AHP approach allows the stakeholders to rank the large number of criteria, which seems to be almost of equal importance according to SD needs. The AHP can be a useful tool for systematically analyzing the opinion of experts for implementing the SBTool 2007 (SBC 08 2007) in the future for Indian conditions. Although the AHP is not the only method for solving decision-making problems, it is widely recognized as an effective tool to provide reasonable and logical solution for the decision-makers. The AHP helps this complex scenario by helping stakeholders to come up with a strategy for the sustainable urban planning of future cities. The hierarchical decision model consisting of final weights of assessment criteria can be very useful for further developing the GB assessment model. The developers should attend to energy efficiency, water efficiency, and environmental loading on a priority basis, with a target to achieve real SUD. The authors hope that the results will be used for future GB assessment studies in developing countries similar to India. The following are general recommendations for the Indian construction industry:

- Building performance needs to be checked for all buildings by the construction industry to achieve SUD;
- All parameters should be considered, including economic, environmental, social, as well as cultural, and multiple stakeholders should be involved to decide performance assessment tool development; and
- Consultants and designers must attend to energy, water, and environmental loading as the most crucial issues while preparing designs of the buildings and must incorporate innovative ideas to save depleting resources.

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