Developing a Sustainable Building Assessment Tool (SBAT) for Developing Countries—Case of India

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suchith reddy Arukala
National Institute of Technology, Warangal

P. ANAND Raj
National Institute of Technology, Warangal

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A. Suchith Reddy, A.M.ASCE[1]; P. Anand Raj, Ph.D., C.Eng[2]; and P. Rathish Kumar, Ph.D., Dr.Eng.[3]

[1]Ph.D. Scholar, Dept. of Civil Engineering, NIT Warangal, India 506004. E-mail: asr.nitwarangal@gmail.com
[2]Professor, Dept. of Civil Engineering, NIT Warangal, India 506004. E-mail: a_raj_p@yahoo.co.in
[3]Professor, Dept. of Civil Engineering, NIT Warangal, India 506004. E-mail: rateeshp@gmail.com

ABSTRACT

The rapid building infrastructure development consumes natural/non-renewable resources, generate waste, and releases potentially hazardous emissions into atmosphere affecting the environment, social, economic, and technological aspects (sustainable indicators) throughout their whole life-cycle. This necessitates assessment of the degree of sustainability of the building in developing countries like India considering local context, topography, climatic variations, and regional differences. The comparitive study on most widely used existing assessment tools like LEED, GRIHA, IGBC, and BREEAM reveals that there are some limitations when applied to Indian context. The objective of the study is to quantify and assess the performance of new and existing buildings towards sustainability by interrelating the sustainable indicators and their criteria. This evaluation approach provides a deep insight into developing a sustainable building assessment tool (SBAT), which can be referred and recommended in assessing the sustainable building performance compared to various available tools. The developed holistic framework will facilitate the decision makers/stakeholders to improve the sustainable performance of buildings in developing countries like India.

INTRODUCTION

More than half of the world's population are in urban settings (Associated Press 2008). According to the United Nations(UN) estimate, by the year 2050 about 6.3 billion people live in the cities around the globe (Tathagat & Dod 2015) (see Figure 1a,1b). It is evident from these curves that beyond the year 2020 the % of urbanization and energy consumption demand is increasing asymptotically. These urban dwellers require housing, transportation, health, education and infrastructure facilities which are a challenging transformation to urbanisation. This unplanned and rapid growth of urbanisation impends the sustainable development, further leading to environmental degradation, social inequalities and economic instability. Owing to the part of urban dweller resource consumption, today's cities consume two-thirds of the world energy accounting to 70% of the Greenhouse Gas (GHG) emissions (McCormick et al. 2013) (see Figure 1c). It is evident that compared to other countries the emission of GHG is mainly from china and India.

Built Environment

The growing urbanisation demand in developing countries like India is accompanied by a rapid increase in energy consumption and carbon emissions. Building sector accounts for 33% of total Indian energy consumption (Economic Policy Forum 2014). So unless specific policies are implemented, this energy demand will further increase to as high as five times by the year 2100 (Vyas & Jha 2016). This acute problem of urban development in India will face monumental challenges (Smith, 2015). According to The Energy Resources Institute (TERI), India needs vast measures on energy efficiency (Singh et al. 2016). For this enormous growth in urban transformation, the only challenging solution for the present scenario is the paradigm shift in sustainable urban development.

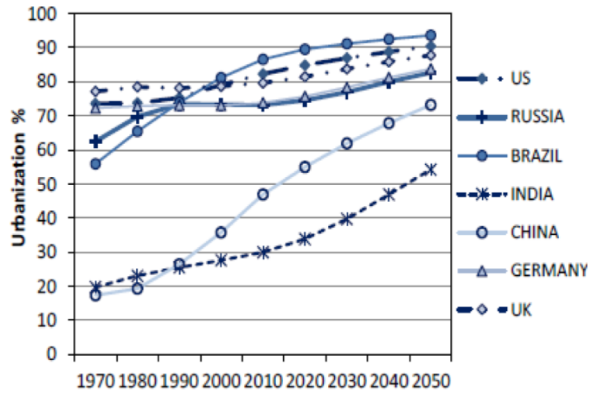

Figure 1a. Total urbanisation between 1970 and 2050 for various countries (Source: Berardi 2015)

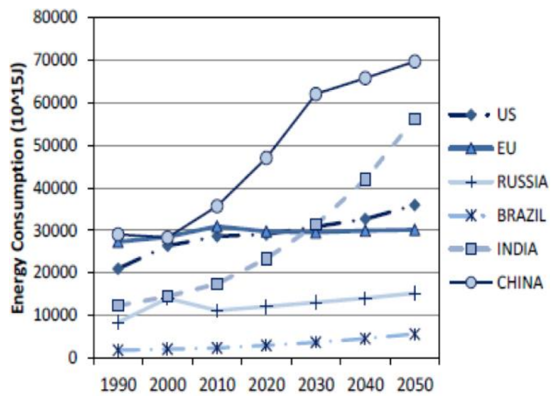

Figure 1b. Residual Building Energy consumption in various countries (Source: Berardi 2015)

Indian Sustainable Built Environment

Building construction uses land, energy, water, and natural resources, produce waste and releases hazardous gases causing ecological imbalance. Incorporating sustainable principles in the construction sector, the buildings can develop the capacity to curtail GHG emissions and reduce the carbon footprint (Jain et al. 2013). Buildings not only have negative impacts in their pre-construction and construction phase but also during the operation and maintenance (post-construction) phase. To impart sustainability in the building sector, a green/sustainable building is defined as “a building that can coexist with nature, maximise resource conservation (energy, land, water and materials), reduce pollution in its whole life cycle and deploy the efficient use of space" (IGBC Green New Rating Sytem version 3.0. 2015). The stakeholders of sustainable buildings shall realize that these do not only have sustainable performance but also has pay off fiscally (Jain et al. 2013). Compared to developed countries, developing countries have got new trend in accepting the green building guidelines (Korkmaz et al. 2008). According to United States Green Building Council (USGBC 2014), every country is in the procedure of developing their own rating system or guidelines to achieve overall sustainable built environment. For example, prominent assessment tool like the Leadership in Energy and Environmental Design (LEED) scheme in the US, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan. The Building Research Establishment's Environment Assessment Method (BREEAM) in Australia also use in the country specific format of Norway, Sweden, Spain, and Netherlands. Based on the LEED revision, India introduced the Indian Green Building Council (IGBC) assessment method in the year 2000. Subsequently, The Energy and Resources Institute (TERI) has developed Indian national green building rating system, Green Rating for Integrated Habitat Assessment (GRIHA) in 2007 (Vij et al. 2010).

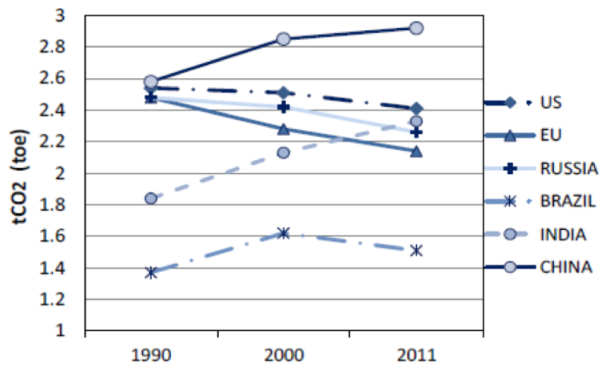

Figure 1c. CO_2 equivalent emissions per Primary energy supply (in tonne of oil equivalent) in various countries (Source: Berardi 2015)

Comparison of Assessment tools

There are several building assessment tools available in the world. Some of them are the most prominently used tools are compared with their criteria and sub-criteria. According to Cole 2005, the development of assessment tool from a comparative analysis of existing ones is a dynamic start for new assessing methods. Therefore, various criteria, sub-criteria, and attributes are summarized and compared with the exiting assessment tool (BREEAM, LEED, IGBC, and GRIHA) to understand the depth of significance of each of the criteria and their related sub-criteria which contribute to achieving the sustainability and identify the potential criteria (see Table 1). The symbol '√'represents that the attribute is included in the respective assessment tool, whereas 'x' represents that it does not. Some of the indicators which contribute to the building sustainability are neither included in IGBC nor GRIHA. Similarly, the indicators which are included in IGBC are not included in GRIHA and vice-e-versa. For example, ventilation, CO_2 emissions, and material efficiency. Irrespective of these, some criteria like topographical consideration, climatic conditions, local context, regional variations are not at all considered.

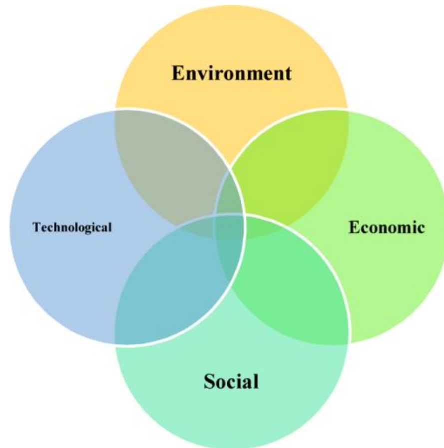

Figure 2. Schematic diagram showing Dimensions /Indicators of Sustainability

Need for the Study

A building construction project is considered as sustainable only when all the dimensions of sustainability are taken into account. Most of the issues of sustainability are interrelated like in existing methods, focus is mainly given on environmental aspects. However, presently, there is no specific assessment tools that encompasses the environmental, economic, social and technological aspects of the assessment (Banani et al. 2016) (see Figure 2). This indicates disregard to economic, social and technological aspects of sustainability, which could further lead to ecological imbalance and thereby miss the real goal of sustainable development. India exhibits a range of different climates, cultures, and topographic features and would thereby benefit from incorporating these features in sustainable building assessment method (Alyami & Rezgui, 2012) . Though the LEED has attempted to make their assessment tools compatible with conditions of different regions in the world it was not able to fully incorporate the social, economic and cultural elements in the sustainability assessment criteria (Banani et al., 2016). The existing building assessment tools are hence limited to unidimensional sustainability. Sustainable building assessment should be based on triple bottom line approach (Bhatt et al. 2010) i.e., environment, social, and economic dimensions. It was also observed that the building assessment criteria were developed to originally suit a specific region. In line with (Horvat & Fazio 2005; Sev 2011), LEED and BREEAM hence overlooked some of the sustainable criteria and category. According to (Alyami et al. 2015), in Saudi Arabia socio-cultural, economic and general management aspects are included in the existing assessment tool. Similarly, Ding (2007) advised that the building assessment method has a variety of criteria. Therefore, for Indian scenario the strategy for assessing the building performance towards sustainability shall be to include all the dimensions of sustainability related to Indian construction industry. The present work attempts to incorporate technological dimension by rejuvenating the ideas of reuse, recycle, reduce, renew, and regenerate into implementable solutions. In simple words, to transform a theoretical concept into practical implementation, firstly, it needs various techniques and methodologies for benchmarking the threshold values and targets. Secondly, it needs policies and guidelines for proper governance in particular. Finally, it is necessary to understand that the co-benefits of supporting technique and technology lead to sustainable harmony in the construction industry. The significance of this study lies in the development of the framework to determine the relative weights of four sustainable indicators: Environment, Social, Economic and Technological using Analytical Hierarchy Process (AHP), a Multi Criteria Decision Making

(MCDM) method.

Table 1. Criteria comparison of most prominently used assessment tools

Criteria	Sub-criteria	Attribute	BREEAM	LEED	IGBC	GRIHA
Sustainable site and ecology	Construction site	Selection of site	√	√	√	√
		Protection of site	√	√	√	√
	Ecological value	Land contamination	√	√	√	√
		Mitigating ecological impact	√	√	√	√
		Balancing site ecology	√	√	√	√
		Protecting biodiversity	√	√	√	√
	Transport	Ease of accessibility	√	√	√	√
		Developing density	√	√	√	X
		Inter community network	√	√	√	X
		Safety of pedestrian	√	√	X	X
		Car parking facility	√	√	√	X
Energy efficiency	Energy performance	HVAC	√	√	√	√
		Rate of ventilation	√	√	√	X
		Internal and external lighting	√	√	√	√
		Provision of hot water	√	√	√	√
		Heat transmission	√	√	X	X
		Renewable technology on energy	√	√	√	√
		Monitoring energy	√	√	√	X
		Energy saving	√	√	√	√
		CO2 strategy	√	√	√	X
Water efficiency and water management	Water	Reducing consumption of water	√	√	√	√
		Harvesting water	√	√	√	√
		Recycling of water	√	√	√	√
		Innovative water recycling technology	√	√	√	√
		Water conservation technique	√	√	√	√
		Water irrigation technique	√	√	√	√
		Ground water recharge	√	√	√	√
Material	Material category	Low impact environment material	√	√	√	√
		Use of non- renewable resources	√	√	X	X
		Material reuse	√	√	√	X
		Using innovative technology for non structure	√	√	√	X
		Insulating component	√	√	X	X
		Material finishing	√	√	√	X
		Local resources utility	√	X	√	X
		Efficiency of material over LC	√	√	X	X
Pollution and risk	Emissions and disaster	Global warming potential for refrigerant	√	√	√	X
		Noise pollution	√	√	√	X
		Preventing pollution leaks	√	X	√	X
		Water pollution	√	√	X	X
		Effect of heat island	√	√	√	X
		Source of NO_x emission	√	√	X	X
		Carbon emission	√	√	√	X
		Fire safety	√	√	X	√
		Natural Disaster	√	√	X	X
Indoor environment quality	Noise and acoustics	Level of noise emitting	√	√	X	√
		Insulation to sound source	√	X	X	√
		Absorption of sound acoustics	√	X	X	√
		Active lighting	√	√	√	√
		Lighting control	√	√	√	√

Criteria	Sub-criteria	Attribute	BREEAM	LEED	IGBC	GRIHA
	Lighting and illumination	Open view	√	√	√	X
		Measuring and control on glaring	√	√	X	X
		Level of illumination	√	√	√	X
		Daylight factor	√	√	√	X
	Ventilation	Natural ventilation	√	√	√	√
		Type of ventilation	√	√	√	√
		Supply of purified and fresh air	√	√	√	√
		Air monitoring sensor	√	√	√	X
		Monitoring on carbon emission	√	√	√	
	Contamination level	Unstable compounds	√	√	√	√
		Pollution of electromagnetic waves	X	X	X	X
		Level of microbiological content	√	√	X	X
	Thermal comfort	Controlling zone	√	√	X	X
		Heating, cooling, humidity, vapour control and their comfort	√	√	√	√

Source: (Alyami & Rezgui 2012); (Vyas & Jha 2016)

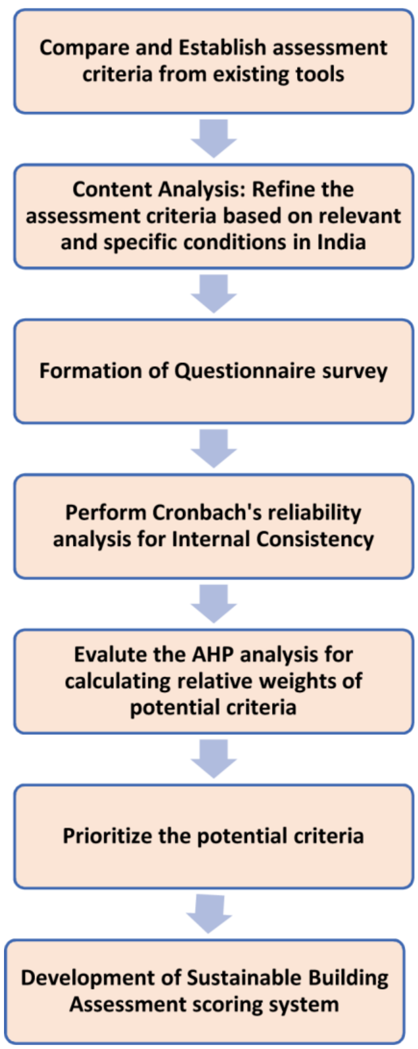

Figure 3. Methodology for developing a Sustainable Building Assessment Tool (SBAT)

RESEARCH METHODOLOGY

The assessment methods created for one nation or region were not applicable to others because, a number of factors prevent the transfer of currently available assessment tools to other nations (Banani et al. 2016; Mao et al. 2009; Alyami & Rezgui 2012). Some of these factors include site conditions, climate, geography, resource consumption, level of public awareness etc. to state a few. The present study is hence designed to first develop an assessment criteria for sustainable buildings in India through qualitative research methods. The resultant criteria was then used to develop priorities and weights through quantitative research methods. Data has been collected from three main sources: literature, comparison of existing assessment tools and structured and unstructured questionnaires. The study has been designed in three phases: Comparing and establishing, refining, and weighting and prioritizing the assessment criteria (see Figure 3). The respondents were invited to assess the level of importance of those criteria (see Table 2) with respect to Sustainable indicators by assigning a score on the Likert scale (between 1 and 7). A questionnaire was designed in such a way that helps to perform the decision making analysis easily. A score of '1' indicates as 'not important' whereas, '7' indicates 'highly important'. Further, the reliability test of the data was checked with Cronbach's alpha using SPSS software. The Cronbach's alpha coefficient for the data is observed to be more than 0.7, which is considered as reliable and consistent. A total of 58 professionals were invited to participate in the survey and their details are as follows:

- 18 Academicians (1 < experience < 20)
- 17 Client/engineer (1 < experience < 20)
- 8 Contractors (1 < experience < 20)
- 2 Designers (1 < experience < 3)
- 5 Architects (1 < experience < 3)
- 5 Consultants (1 < experience < 20)
- 3 Others (1 < experience < 20)

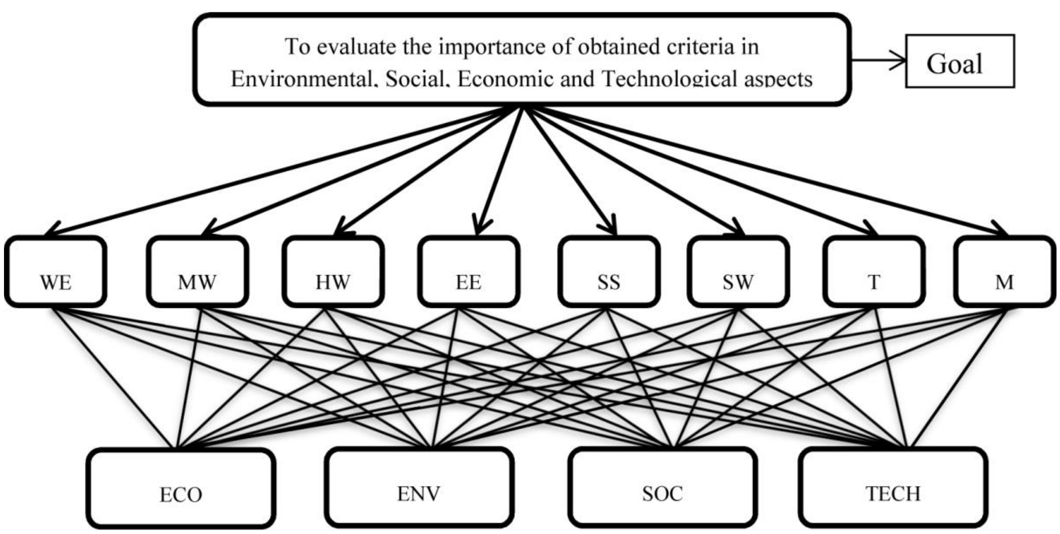

Figure 4. Hierarchical structure for proposed Sustainable Assessment Criteria with respect to Indicators

Table 2. Most prominent criteria and sub-criteria evaluated for Indian context

Code	*Criteria*	*Sub-criteria*
WE	Water efficiency	Water monitoring and leak detection Building water use reduction Minimize portable water use Recycle and reuse of water Rainwater management Efficient landscaping
MW	Materials and waste management	Low-energy materials Regionally available materials Recycled and re-use materials Responsible sourcing Efficient waste management Recycled aggregates
HW	Health and well-being	Visual and thermal comfort Water quality & water pollution Outdoor & indoor noise levels Reduce air pollution Sanitation/Safety facilities & Accessibility Minimize ozone depletion
EE	Energy efficiency	Renewable energy production Energy efficient design Energy monitoring Refrigerant management/Green power Optimize energy performance Vertical transportation
SS	Sustainable sites	Site selection Protect or restore habitat Heat island reduction Open space Joint use of facilities Site improvement plan
SW	Social welfare	Sustainable or environmental education Responsible construction practices Design for durability Health, well-being, and accommodation Employment opportunities Innovation
T	Transportation	Green vehicles/Alternative modes of transport Bicycle facilities Proximity to amenities Public transport accessibility Home office Reduced parking footprint
M	Management	Project brief and design Site management Life cycle costing Audit and validation Commissioning and handover Aftercare

Formulation of Sustainable Building Rating System

The observed criteria and sub-criteria for Indian context (see Table 2). To determine the relative importance of sustainable criteria and indicators, AHP method is utilized and it requires a hierarchical structure that descends from the primary goal to category and sub-category in subsequent levels (see Figure 4), for assessing the sustainability of buildings. To weigh and prioritize the sustainable criteria considering indicators, AHP method requires three steps: 1) Structuring the hierarchy, 2) Establishing pairwise comparison matrix, 3) Weightage and priority analysis (Saaty 2008). The pairwise comparison focuses on subjective judgements to calculate the weight vector using the principle of eigenvector, and finally prioritize the sustainable criteria in the order of preference. For finding the importance of derived criteria, eight categories were identified in the first hierarchy level (see Figure 4). Each category consists of four sub-categories, thus a total of 464 no's of 4×4 pairwise comparison matrices was made for each questionnaire to assess the relative weight. Depending on the relative weights of the respective criteria to an indicator (see Figure 5), the indicator which has attained the highest weight is grouped in three different groups for formulating a sustainable building assessment scoring system (see Figure 6).

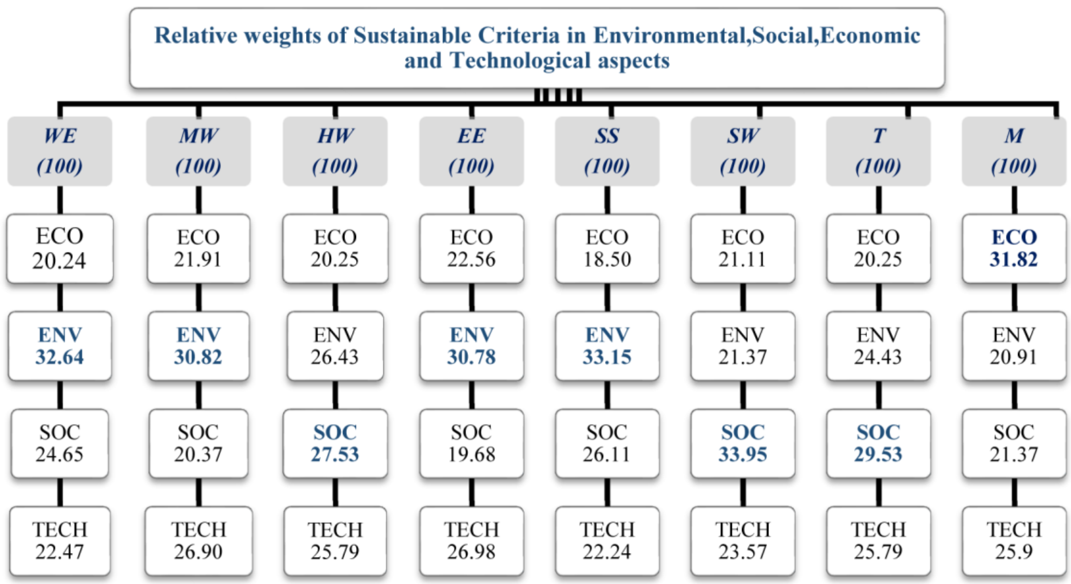

Figure 5. Hierarchy and relative weights of criteria

There are several approaches to evaluate the sustainable building assessment keeping in view the characteristics and local context (Boutkhoum et al. 2016). A qualitative and quantitative approach is desired to evaluate the building assessment more precisely. To develop a Sustainable Scoring System the following approach has been implemented as (see Figure 7).

1) Based on relative weights, significance is given to the criteria and indicator to frame out the scoring system, which is a similar approach in the case of LEED assessment method. From the survey, the level of significance was obtained for each criterion from 58 respondents (see Table 2) with respect to four sustainable indicators by assigning a score to the adopted scale. The sustainable building assessment score was obtained by aggregating the scores of the criteria into a single score for each criterion.
2) The weights were then obtained from each respondent and the resultant weight of each criterion was calculated (see Figure 7).
3) Based on the aggregation of all the resultant weights of each criterion the sustainable building assessment score was obtained.

DATA COLLECTION AND ANALYSIS

From the results obtained (see Figure 5), it can be observed that the technical aspects of the sustainability was given the least weightage compared to all other aspects, and economic (ECO) aspect was considered to be important only in management criteria. Also, the environmental indicator (ENV) has been even more importance in sustainable sites and water efficiency, with a weightage of 33.15% and 32.64% and has the least importance in management with 20.91%. Similarly, the social indicator (SOC) has the highest importance in social welfare, with a weightage of 33.95% and least importance in energy efficiency, with a weightage of 19.68 %. The technological indicator (TECH) has more importance with respect to energy efficiency with a weightage of 26.98 % and has least importance in sustainable sites with a weightage of 22.24%.

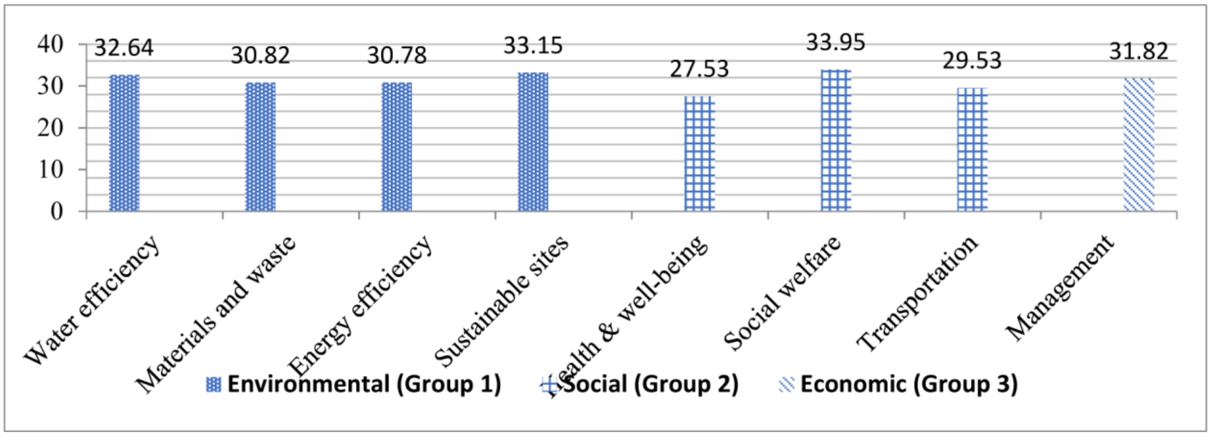

Figure 6. Summary of three different groups and their criteria weights

The present study refined eight major criteria that were similar to some systems and different from the others. The obtained criteria scores based on the approach (see Figure 7) are: 1) Water efficiency (17.31); 2) Materials and waste (17.51); 3) Health & well-being (16.64); 4) Energy efficiency (17.16); 5) Sustainable sites (17.21); 6) Social welfare 7) Transportation (15.10); 8) Management (11.23). The total maximum points given for this system were 128. Each criterion consists of a number of sub-criteria and the scores for each criterion were divided and allocated to sub-criteria based on the expert's opinion and ranking. The assessment system certification criterion was based on summation of scores of sub-criteria for a maximum score of 128 points. The research proposed three performance levels namely, One star (91 and above), two star (61–90) and three star (<60 points).

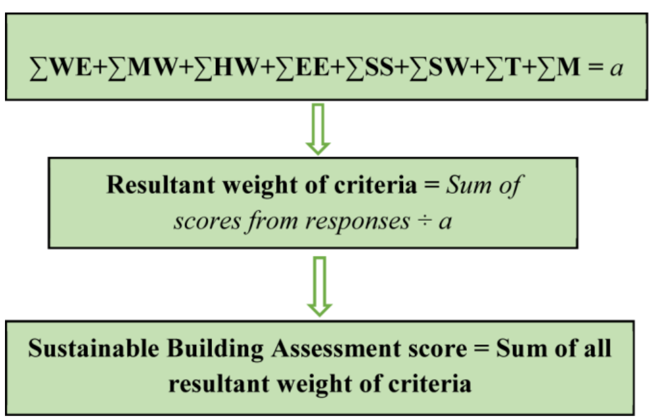

Figure 7. Approach for Sustainable Building Scoring System

CONCLUDING REMARKS

It was noticed based on the survey and analysis that the identified four dimensions of sustainability play a crucial role in assessing the criteria in the Indian context. The study identified eight criteria and 48 sub-criteria as the most appropriate assessment criteria for assessing the performance of sustainable construction in India. The criteria include water efficiency, materials and waste management, health and well-being, energy efficiency, sustainable sites, social welfare, transportation, and management. The identified criteria can be used in policy making, guidelines, and development of green building rating tool. From the results, it can be observed that water efficiency, materials and waste, energy efficiency and sustainable sites have importance from the environmental aspects; and health and well-being, social welfare and transportation are having importance in both social and economic aspects; and management has major importance in technological aspect. However, the overall result reveals that the environmental aspects are the most important aspects than the other aspects. In fact, the SBAT aimed at incorporating local context, regional variation, climatic conditions and topographical aspects by crucially observing a number of criteria and sub-criteria to reflect and diagnose regional sustainability. India is a developing country, which is promoting sustainability in the construction industry, hence there is an imperative need for encouraging and adopting sustainability principles to avoid adverse impacts on conventional principles and practices in India. Therefore, the approach adopted for developing SBAT is simple, more reliable and user-friendly.

REFERENCES

The Associated Press. (2008). UN says half the world's population will live in urban areas by end of 2008. International Herald Tribune. http://www.iht.com/articles/ap/2008/02/26/news/UN-GEN-UN-Growing-Cities. php.

Alyami, S. H., & Rezgui, Y. (2012). "Sustainable building assessment tool development approach." *Sustainable Cities and Society*, *5*(1), 52–62. https://doi.org/10.1016/j.scs.2012.05.004

Alyami, S. H., Rezgui, Y., & Kwan, A. (2015). The development of sustainable assessment method for Saudi Arabia built environment: weighting system. *Sustainability Science*, *10*(1), 167–178. https://doi.org/10.1007/s11625-014-0252-x

Banani, R., Vahdati, M. M., Shahrestani, M., & Clements-Croome, D. (2016). "The development of building assessment criteria framework for sustainable non-residential buildings in Saudi Arabia." *Sustainable Cities and Society*, *26*, 289–305. https://doi.org/10.1016/j.scs.2016.07.007

Berardi, U. (2015). "Building Energy Consumption in US, EU, and BRIC Countries." *Procedia Engineering*, *118*, 128–136. https://doi.org/10.1016/j.proeng.2015.08.411

Bhatt, R., Bhatt, D., & Patel, V. (2010). "Analytic Hierarchy Process Approach for Criteria Ranking of Sustainable Building Assessment : A Case Study." *World Application Science*, *8*(7), 881–888.

Boutkhoum, O., Hanine, M., Boukhriss, H., Agouti, T., Tikniouine, A., Ageron, B., Peng (2016). "Multi-criteria decision support framework for sustainable implementation of effective green supply chain management practices." *SpringerPlus*, *5*(1), 664. https://doi.org/10.1186/s40064-016-2233-2

Cole, R. J. (2005). "Building environmental assessment methods: redefining intentions and roles." *Building Research & Information*, *33*(5), 455–467. https://doi.org/10.1080/09613210500219063

Ding, G. K. C. (2007). "Life cycle assessment (LCA) of sustainable building materials: an

overview", *Building Research & Information,* 1–20.
Economic Policy Forum. (2014). Promoting sustainable and inclusive growth in emerging economies : Green Buildings, 1–62. Retrieved from https://economic-policy-forum.org/wp-content/uploads/2016/02/Sustainable-and-Inclusive-Growth-Green-Buildings.pdf
Horvat, M., & Fazio, P. (2005). “Comparative Review of Existing Certification Programs and Performance Assessment Tools for Residential Buildings.” *Architectural Science Review, 48*(1), 69–80. https://doi.org/10.3763/asre.2005.4810
IGBC Green New Rating Sytem version 3.0. (2015). Abridged Reference Guide, 146.
Jain, M., Mital, M., & Syal, M. (2013). “Obstacles and Catalysts Associated with Implementation of LEED-EB(R) in India.” *Environment and Urbanization Asia*, *4*(2), 349–363. https://doi.org/10.1177/0975425313511164
Korkmaz, S., Erten, D., Syal, M., & Potbhare, V. (2009). “A review of green building movement timelines in developed and developing countries to build an international adoption framework.” *In Proceedings of Fifth International Conference on Construction in the 21st Century: Collaboration and Integration in Engineering, Management and Technology* (pp. 20–22*)*.
Mao, X., Lu, H., & Li, Q. (2009). “A comparison study of mainstream sustainable/green building rating tools in the world. *Proceedings” - International Conference on Management and Service Science, MASS 2009*. https://doi.org/10.1109/ICMSS.2009.5303546
McCormick, K., Anderberg, S., Coenen, L., & Neij, L. (2013). “Advancing sustainable urban transformation.” *Journal of Cleaner Production*, *50*, 1–11. https://doi.org/10.1016/j.jclepro.2013.01.003
Saaty, T. L. (2008)."Decision making with the analytic hierarchy process". *International Journal of Services Sciences*, *1*(1), 83. https://doi.org/10.1504/IJSSCI.2008.017590
Sev, A. (2011). “A comparative analysis of building environmental assessment tools and suggestions for regional adaptations.” *Civil Engineering and Environmental Systems*, *28*(3), 231–245. https://doi.org/10.1080/10286608.2011.588327
Singh, S., Lal, R. B., Sridharan, U., & Upadhyay, V. P. (2016). “Environmental Sustainability Guidelines for Green Buildings in India: A Review.” *Indian Journal of Scientific Research and Technology*, *4*(1), 2321–9262. Retrieved from www.indjsrt.com
Smith, R. M. (2015). “Green building in India: A comparative and spatial analysis of the LEED-India and GRIHA rating systems.” *Asian Geographer*, *32*(2), 73–84. https://doi.org/10.1080/10225706.2015.1020065
Tathagat, D., & Dod, R. D. (2015). “Role of Green Buildings in Sustainable Construction-Need, Challenges and Scope in the Indian Scenario". *IOSR Journal of Mechanical and Civil Engineering Ver. II*, *12*(2), 2320–334. https://doi.org/10.9790/1684-12220109
USGBC. (2016). LEED v 4 for Neighborhood Development, 161. Retrieved from http://www.usgbc.org/sites/default/files/LEED v4 BDC_04.05.16_current.pdf
Vij, A., Shorey, G., Zia, H., Majumdar, M., Shukla, P., Kumar, P., Tripathi, A. K. (2010). GRIHA Manual, *1*, 129. Retrieved from ttp://www.grihaindia.org/files/Manual_VolI.pdf
Vyas, G. S., & Jha, K. N. (2016). “Identification of green building attributes for the development of an assessment tool: a case study in India.” *Civil Engineering and Environmental Systems*. https://doi.org/10.1080/10286608.2016.1247832