Review and Assessment of Factors Associated with Green Building Rating Systems

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Abstract. Globalization has created rapid development in every sector, especially in the infrastructure and real estate sector. Building and construction industry is responsible for energy-related CO₂ emissions through the manufacturing of building materials, products and also have adverse impacts on non-renewable resources. For mitigation of these adverse impacts, green construction practices are encouraged by most of the countries in the world by developing various green building rating systems. These systems include criteria like energy efficiency, passive design aspects, renewable energy systems incorporation, life cycle assessment (LCA), post-occupancy evaluation, site planning, and resources conservation aspects and innovations which are common in most of the countries' rating systems. Although we have these green rating systems, the construction practices and on-site actions of contractors, architects, engineers, and consultants play a very crucial role in the implementation of these green principles. This paper aims to investigate the gaps between the theories of green rating systems and the adoption of the green specifications actually in practice in construction projects. This will help to point out the hurdles in the adoption and execution of green construction practices and also suggest the useful implications for government, construction companies, and green building councils for better application of green construction practices on sites.

Keywords. Green building rating systems; Sustainability; Energy Efficiency; Questionnaire survey; Analytical Hierarchical Process (AHP)

1. Introduction

In today’s world, the need of the hour is the development of the human society through practicing a more sustainable approach because we are facing many global issues out of that few issues like climate change, energy shortage, rapid urbanization, increasing population are creating difficult challenges for sustainable development in countries. Since 1880, the global average temperature increased by 1.8° F as per the NASA reports [1], and further, by 2050, it is expected to increase by about 4.5° F only because of the increase in CO₂ alone[2]. As statistically around 30-40% of the raw materials and final energy use are consumed by the construction industry [3]. As a result, the construction sector is accountable for the generation of 39% of energy-related CO₂ emissions in 2018 and also generates a large amount of waste due to on-site construction activities [4]. In terms of energy consumption globally, energy demand for space cooling, appliances, and water heating increased more than 33%, 18%, and 11% respectively in 2018 since 2010 [5]. Amongst all the present countries in the world, under the United Nations Framework Convention on climate change (UNFCCC), today there are 184 countries that have contributed to NDCs to limit greenhouse gas (GHG) emissions [6].
A ‘green building’ concept is focused on reducing negative impacts, and enhancing our climate and the surrounding environment through effective design, construction, or operation strategies. According to the U.S. Environmental Protection Agency (EPA), the concept of Green Building is to create structures that enhance the environment, sustainable, and resource-efficient throughout the life cycle of the building [7].

2. Literature review

2.1. Sustainable development
The concept of sustainable development is mainly focused on three pillars together in Society, Economy, and Environment. The first prominence is given to the sustainable development concept in the United Nation Conference on Environment and Development (UNCED) in “The Earth Summit” in Rio 1992 [8]. Sustainable development is made up of two terms ‘sustainability and ‘development’ this indicates a growth pattern that improves and strengthens both national capabilities to care for their people in relation to the resources on the earth. Sustainable development goals (SDGs) and their planning were done by leaders of the 193 countries in the year 2015 to improve the environmental conditions. A total of 17 SDGs is set up to get rid of poverty, hunger, and safe from the worst effect of climate change in the next 15 years. United Nations development program UNDP is one of the leading organizations working on these SDGs.[9]

2.2 Green Building and Sustainability
Green building strategies help to meeting these sustainable development goals and out of 17 goals, we can achieve 9 goals if worked on the green building's principles and the built environment. The concept of green construction is not new, but the techniques are emerging with time. [10]

2.3 Benefits of green buildings
These are the most cost-effective way to achieve global sustainable goals. Apart from environmental benefits, green buildings help to create economic, health, and community benefits [11]. Economic benefits are like Low utility bills for occupants in the building because of greater energy and water efficiency. Health and community benefits like indoor air quality improvement, better thermal comfort, and quality of life.

2.4 Green Building Rating Systems
Worldwide many countries are using international and nationally developed green rating systems because they have different climatic conditions, building types, economic and social priorities. Most famous amongst them are BREEAM -the U.K. which was the first green rating system, and LEED- U.S.A, Green Globes-Canada, Green Star- Australia which is also used in New Zealand and South Africa after customization into their national version which is mentioned in the following timeline.[12]
Figure 2. Sustainable development goals are achieved through the use of green principles.[14]

Table 1. A detailed description of a few of the most known Green building rating systems of different countries.[12], [13], [14], [15], [16]

| Green rating Systems /Establishment year/Country of origin/ Introduction | Certification levels | Categories |
|---|---|---|
| BREEXAM 1990, United Kingdom | Unclassified - <30% Pass - ≥30% Good - ≥45% Very good - ≥55% Excellent - ≥70% Outstanding - ≥85% | Energy - 19, Materials - 12.5, Waste - 7.5, Pollution - 10, Health & well-being - 15, Water – 06, Transport- 08, Land use and Ecology-10, Management - 12, Innovation - 10 |
| LEED 1998, United States | Certified-40-49 points Silver-50-59 points Gold-60-79 points Platinum -80+ points | Energy and Atmosphere -35, IAQ – 15, Innovation in design -06, Material and resources -14, Regional priority- 04, Sustainable sites -26, Water efficiency -10 |
sustainability of buildings.[13]

| Green star 2002, Australia | One-star Green star - 10-19 points | Management – 14, IEQ – 17, Energy – 22, Transport – 10, Water – 12, Material – 14, Land use & Ecology – 06, Emissions – 05, Innovation |
|-----------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Green Star is launched by the Green Building Council of Australia. It is also used in South Africa and New Zealand in their nationally converted version.[14] | Two-star Green star - 20-29 points |                                                                                                                                  |
|                             | Three-star Green star -30-44 points |                                                                                                                                |
|                             | Four-star Green star - 45-59 points |                                                                                                                                |
|                             | Five-star Green star - 60-74 points |                                                                                                                                |
|                             | Six-star Green star - 75-100 points |                                                                                                                                |

| CASBEE 2003, Japan          | C (Poor) – 0.5 | Q1 –i) Noise and Acoustics- 0.15, ii) Thermal comfort – 0.35, iii) Lighting and Illumination – 0.25, iv) Air quality - 0.25 |
|-----------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------|
| Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) was developed by coordinated efforts of government, industry, academia, and the Japanese Ministry of land, transport, and infrastructure. [14],[17] | B- -0.5-1 | Q2 –i) Serviceability – 0.4, ii) Durability & Reliability – 0.3, iii) Flexibility & Adaptability- 0.3 |
|                             | B+ - 1-1.5 | Q3 -i) Preservation and creation of biotope- 0.3, ii) Townscape and landscape- 0.4, iii) Local Characteristics & outdoor amenity. – 0.3 |
|                             | A - 1.5-3 | L1 –i) Building thermal load – 0.2, ii) Natural energy utilization – 0.1, iii) Efficiency in building service system – 0.5, iv) Efficient operation – 0.2 |
|                             | S (Excellent) - >3 | L2 –i) Water resources – 0.2, ii) Reducing the usage of Non-renewable resources – 0.6, iii) Avoiding the use of materials with pollutant content - 0.2 |

| Green Mark 2005, Singapore | Certified -50 to <75 | Environmental protection – 41, IEQ – 06, Innovation and other green features – 07, Water efficiency – 14, Energy efficiency - 87 |
|-----------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------|
| It was developed by the Singapore construction industry towards a more sustainable building environment and to raise awareness among builders, developers, and designers. | Gold - 75 to <85 |                                                                                                                                 |
|                             | Gold Plus- 85 to <90 |                                                                                                                                 |
|                             | Platinum - 90 and above |                                                                                                                                 |

| | | |
Indian Green Building Council (IGBC)

2001, India

Indian green building council is a part of the Confederation of Indian Industry (CII). It is developed with a vision to build a sustainable environment for the Indian region.

| Certification | 50-59 points | 60-69 points | 70-79 points | 80-89 points | 90-100 points |
|---------------|--------------|--------------|--------------|--------------|---------------|
| Silver        |              |              |              |              |               |
| Gold          |              |              |              |              |               |
| Platinum      |              |              |              |              |               |
| Super platinum|              |              |              |              |               |

GRIHA

2006, India

Green Rating for Integrated Habitat Assessment is an Indian rating system jointly developed by TERI and the Ministry of New and Renewable Energy, Government of India to minimize buildings resource consumption, waste generation, and overall ecological impact.

| Certification | 25-40 | 41-55 | 56-70 | 71-85 | 86 or more |
|---------------|-------|-------|-------|-------|------------|
| Silver        |       |       |       |       |            |
| Gold          |       |       |       |       |            |
| Platinum      |       |       |       |       |            |
| Super platinum|       |       |       |       |            |

There is another green building rating system also which have other unique ways to do building assessment amongst them one emerging rating system is WELL Building Standards founded in October 2014 by International WELL Building Institute (IWBI) launched by an American based organization Delos living LLC [18]. This certification is granted after the building is occupied and focuses exclusively on human health and wellness aspects. According to WELL V2, the building is monitored and measured based on 10 concepts that affect human health and well-being. These 10 concepts are Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind, Community [19]. Every concept focuses on different aspects related to health. These all 10 aspects listed are mandatory for certification. All the ten concepts of WELL Building standards help to achieve a healthy and safe environment for human beings, and this also gives focus on the mental health of users in the building which can be adopted by other rating systems used in different countries for improving their certification program.

Table 2. Conditions, criteria, and details about the WELL Building standards[18], [19], [20]

| Concept and Description | Pre-conditions | Optimizations |
|-------------------------|----------------|--------------|
| Air - This criterion ensures a good level of indoor air quality throughout the building lifecycle. | 4 | 10 |
| Water - This criterion ensures good quality and a sufficient amount of water supplies into buildings. | 3 | 6 |
| Nourishment - This criterion aims to create a food environment to make an easy and healthier choice. | 2 | 11 |
| Light - This criterion aims to create good lighting environments for occupants’ visual, mental, and biological health aspects. | 2 | 6 |
| Movement - This criterion helps to discourage sedentary behaviors’ and promotes physical activity and active living. | 2 | 10 |
| Thermal comfort - This criterion ensures the level of thermal comfort received by the building’s users. | 1 | 6 |
| Sound - It aims to maintain comfortable acoustical parameters in the built | 1 | 5 |
environment.

| Material - It aims to reduce the negative effect of hazardous building material on human health and promotes the use of materials that are safe to handle. | 3 | 11 |
| Mind - This criterion focuses on the mental health aspects which are promoted through various design strategies and policy programs. | 2 | 13 |
| Community - This criterion focuses on healthcare-related aspects of its accessibility to users and also on workplace health, accommodations of users. | 3 | 14 |
| Innovation - To promote a new innovative way to improve health and well-being. | 0 | 5 |

3. Identified gap areas
Through a comprehensive study of literature related to green buildings and green buildings rating system, we found that 4 stakeholders play important roles in the adoption of green buildings construction practices: 1) Policy Makers and Green building councils 2) Manufacturers 3) Professionals and on-site personal related to construction 4) Occupants [20]. Government stakeholders include policymakers, and private stakeholders include professionals, manufacturers, and occupants. The professional stakeholder category includes contractors, architects, engineers, consultants, and on-site personals that play a very crucial role in the construction sector. There is a need to create awareness and motivation among these stakeholders, especially among professionals for better adoption and implementation of these green building guidelines. This paper aims to identify the gaps between the green building rating systems theories and the actual adoption and implementation of these green building rating principles in practice in construction projects.

4. Methodology of research
Through a comprehensive literature review and an extraction from green building rating systems of various countries like LEED (US), BREEAM (UK), GREEN STAR (Australia), IGBC & GRIHA (India), GREEN MARK (Singapore), CASBEE (Japan), etc., a list of few common criteria and sub-criteria having impacts on green construction have been identified and these are classified under five main criteria and further, these classified into 12 sub-criteria and hierarchy of these all factors is as per figure 4. The questionnaire survey is conducted among professionals and on-site personals related to construction. Further, the Analytical Hierarchical Process (AHP) analysis is used to analyses responses by making pair-wise comparisons among all the above-mentioned criteria and sub-criteria. This survey is aimed to find out which factors have given more importance over other factors in practice in existing and on-going construction-related projects.

![Hierarchy diagram of 5 main criteria and 12 sub-criteria related to construction projects.](image)
For this purpose, the Analytical Hierarchy Process (AHP) used which was developed by Thomas L. Saaty; this includes a pair-wise comparison of all factors with a rating system based on Saaty’s scale [16].

5. Discussion

5.1 Questionnaire survey analysis

The questionnaire survey responses are recorded of architects, civil engineers, consultants, professionals, and on-site personals related to construction. Data from 132 respondents were received, out of which two responses were deleted after filtering as they were duplicated, and 130 responses were used for further analysis.

![Figure 5. Comparison of local weights distribution for all five main criteria.](image)

Through the questionnaire survey, we found weights for all five main criteria in which mechanical means of human comfort systems have given very much importance over any other criteria and the secondary importance is given to the criterion of sustainability design aspects associated with construction. The passive design strategies criteria have given very little importance in practice, although it is very much significant to minimize energy consumption and pollution in the construction sector. Also, the criterion post-occupancy health and wellness of building’s occupants has given lesser importance in practice over other three criteria, and it should be given more importance as it is related to occupants living and comfort conditions in a particular structure, and also includes various performance-based factors which have effects on human health and wellbeing. The recorded data is consistent because the consistency ratio (CR) is 0.0160, which less than 0.1. Further analyzed and calculated the weights given by respondents to all sub-criteria. (CR = CI/RI).

![Figure 6. Various factors for checking the consistency of data and percentage distribution of weights given to sub-criteria of passive design strategies.](image)
Figure 7. Percentage distribution of weights given to sub-criteria of mechanical means of human comfort systems and sustainability aspect associated with construction.

Figure 8. Percentage distribution of weights given to sub-criteria of post-occupancy health and wellness of buildings’ occupants and renewable energy usage & innovative strategies.

The local weights of criteria and sub-criteria are calculated, then further global weights for all 12 factors are calculated, which are mentioned in the following table no.3. Through global weights comparison, we can conclude that HVAC systems and water heating-pumping systems have given more importance to existing construction practices. These are the main cause of greenhouse gas emissions and huge costs for maintenance over the lifecycle of the building. Further, due to resource constraints, site planning, and resource conservation have given more weightage, but still, there is a lack of motivation for contractors to use green materials in construction practices.

Table 3. Local weight and global weights distribution for all criteria and sub-criteria

| Local Weights of Criteria | Local Weights of Sub-criteria | Global Weights |
|---------------------------|-------------------------------|----------------|
| Passive design strategies (0.144) | Building envelops, form, shape, and orientation(0.399) | Building envelops, form, shape, and orientation(0.057) |
| | Shading, openings, use of natural lighting and ventilation(0.601) | Shading, openings, use of natural lighting and ventilation(0.086) |
| Mechanical means of human comfort systems (0.245) | HVAC systems and water heating-pumping systems(0.586) | HVAC systems and water heating-pumping systems(0.143) |
| | Generator and artificial lighting (0.414) | Generator and artificial lighting (0.101) |
| Sustainability design aspects associated with construction (0.227) | Sustainable site planning and resource conservation(0.588) | Sustainable site planning and resource conservation(0.140) |
| | Green building materials usage (0.412) | Green building materials usage (0.098) |
| Post-occupancy health and wellness of buildings’ occupants (0.189) | Air, Water, Light, and Sound aspects (0.531) | Air, Water, Light, and Sound aspects (0.101) |
| | Thermal Comfort, Movement, Nourishment, and Community (0.469) | Thermal Comfort, Movement, Nourishment, and Community (0.088) |
Through the analysis of responses, we can conclude that building envelop, form, shape, and orientation have given very little importance in construction practices. In practice, generators and the use of artificial lighting have given more weight to natural lighting and passive design strategies. The sub-criterion thermal comfort, movement, nourishment, and community aspects should be given more importance as it is related to occupants living and comfort conditions in a particular structure. The criterion post-occupancy health and wellness of building’s occupants need to be considered as the main aspect in designs because this aspect focuses on the inhabitants’ wellness and health within the building and also try to explore how human get affected from their surrounding environment.

So, from the above analysis, we can say that although there are green rating systems, still there is a need to create awareness and develop motivation among the architects, civil engineers, consultants, and contractors for better implementation of green construction principles into construction practices.

5.2 Challenges and strategies for better implementation of green building construction principles

The requirement of huge capital costs, lack of resources, lack of skilled personals, etc. are the main challenges in the execution of green construction principles.

5.2.1 Government incentives and regulations. The governments should take some initiative to promote energy-efficient techniques in construction. In the past decades, the ambitious target was set by some countries for green building construction but unable to achieve this target with a proper set of rules. So, financial incentives like reduction in government taxes can encourage the adoption and fossil fuel subsidies should be removed to promote green building principles.

5.2.2 Capital cost. Many contractors are concerned about the adoption of green construction principles as it requires high capital costs but due to the current increasing demand for green buildings in recent years, there are constant increases in green construction investment opportunities, the banks are playing a crucial role in providing required capital for the adoption of green technologies. EDGE (Excellence in Design for Greater Efficiency) – a tool for design of building launched by International Finance Corporation (IFC), which is an alternative offered for existing expensive certification systems and providing energy-efficient and cost-effective solutions for developing countries in Asia.

5.2.3 Market awareness. The government and public bodies should conduct information campaigns about green buildings to overcome the lack of understanding about green construction in society and
construction markets. For the development of the green building principles, efforts and involvements are required from the working professionals, government, administrative people, and occupants.

5.2.4 Resource and Skill Gap. Green skill lacks among architects, engineers, professionals, and on-site personals which are the main problem for green construction principles adoption in many countries. The primary reason for the less availability of skilled laborers and shortages of resources is because of constant changes in requirements of the skills due to rapid changes in technology and practices in recent decades.

6. Conclusion

Although there is a continuous rise in acceptance of green construction concepts in recent years, still, there is no proper detailed information available about the impacts of high-performance building construction on the environment, finance, and economic aspects. The findings showed that more preference is given to mechanical means of human comfort systems in construction practices and very less preference given to passive design strategies and post-occupancy health and wellness of buildings’ occupant’s criteria by contractors, architects, civil engineers, consultants, professionals, and on-site personals. The post-occupancy health and wellness of buildings’ occupants’ criteria are related to occupants living and comfort conditions in a particular structure, and also includes various performance-based factors that have effects on human health and wellbeing. For this purpose, as an example, the new green rating system WELL which is developed by the U.S.A and in this certification and monitoring work is started when the building is occupied by the users, and this will help us to achieve good standards of living and the working environment because we spent around 90% of our times indoors and our buildings should be designed in keeping in mind all the requirements of human beings. The perception of high upfront costs and lack of awareness is seen as a major problem in the adoption of green building concepts. The paper is made an attempt to find out some useful implications using questionnaire survey among construction fraternity which definitely will help governments, administrations, and departments of construction to take measures for ensuring the better implementation of green activities on construction sites.

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