

Performance Assessment of Green Rated Built Environment using Post Occupancy Evaluation



S.G. Sonar, R.V. Nalawade

Abstract: Green Rating Certification is one of the important mechanism developed in last few decades worldwide to achieve sustainability in Built Environment life cycle. The early generations of Green Rated Built Environment from India have occupied for several years now. Therefore, it has become inevitable to assess whether these Built Environment are living up to expectations in their objective terms. Post Occupancy Evaluation is a process of systematic monitoring of Building's performance with predefined parameters and objectives after it is occupied for few years. Present research focuses on assessment of Green Rated Built Environment on the basis of performance parameters. Indoor Environmental Quality (IEQ) and Energy Efficiency are two performance parameters identified for current research. Seven Green Rated Institutional/office projects have been selected for Post Occupancy Evaluation. Indian Green Building Council (IGBC) has rated three projects and Green Rating for Integrated Habitat Assessment (GRIHA) has rated remaining four buildings. All seven projects are located in warm and humid climatic zone of India. Questionnaire Survey, on site measurement of Indoor Environmental Quality parameters and Energy consumption records are selected as a tool to measure performance of Green rated project.

Keywords: Built Environment, Green Building Rating System, Post Occupancy Evaluation

I. INTRODUCTION

The Built Environment is a material, spatial and cultural product of human labor that combines physical elements and energy in forms for living, working and playing. Built Environment defined as the human-made space in which people live, work, and recreate on a day-to-day basis. It describes interdisciplinary field that addresses design, construction, management, and use of Built Environment as an interrelated whole, as well as their relationship to human activities over time.

The growth and development of Built Environment has a large impact on natural environment. Built Environment in which human live and work is responsible for the consumption of many natural resources. Consumption of such natural resources leads to unnecessary use of energy and water, which detrimentally affect health and comfort. It also results in large quantities of waste and creates a huge amount of pollution. Pollution's devastating effects on the environment have become more obvious in recent years highlighting the need for energy efficient design, minimizing dependency on fossil fuels, and reduction in air and water pollution in design considerations. Improvisation in design consideration of Built Environment has achieved reduction in resources consumption while maintaining better Indoor Environment Quality (IEQ). Increasing awareness and rising social responsibility on part of its stakeholders for achieving sustainability, has resulted into adoption of Green Rating initiative in Built Environment. This initiative is one of the mechanisms of improving efficiency with which Built Environment consume energy, water, and other natural resources. It also reduces development impacts on human health and the environment over the entire life cycle of the Built Environment. Green Rating initiative extend beyond the physical elements in Built Environment and can include site planning, community and land use planning issues as well. This kind of initiative has achieved more significance in Indian context as Real Estate Sector is growing rapidly attributing to growth in Tertiary Sector.

II. GREEN RATING INITIATIVES IN INDIAN CONTEXT - RESEARCH NEED

In Indian context, various innovative Green Rating initiatives employed for achieving sustainability in the development of Built Environment. These initiatives include Green Building Rating System by Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA) by The Energy and Resources Institute (TERI), Energy Conservation Building Code (ECBC) proposed by Bureau of Energy Efficiency, etc. IGBC is the country's premier body for Green Rating Certification formed by the Confederation of Indian Industry (CII) in 2001. The vision of the council is, "to enable a Sustainable Built Environment for all". The council offers a wide array of services which include developing New Green Rating Programs, Certification Services and Green Building Training Programs, etc. The council is committee-based, member-driven and consensus-focused.

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* Correspondence Author

S.G. Sonar*, Associate Professor, Department of Civil Engineering, College of Engineering Pune

R.V. Nalawade, M.tech, Research Scholar, Department of Civil Engineering, College of Engineering Pune

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All the stakeholders of construction industry comprising of architects, developers, product manufacturers, corporate, government, academia and nodal agencies participate in the council activities through local chapters. The council also closely works with several State Governments, Central Government, World Green Building Council, and Bilateral Multi-Lateral Agencies in promoting Green Building Concepts in Indian context. IGBC certifies Green Building Projects; those conceptualized, designed, constructed and operated as per IGBC rating system. The rating system based on the five elements of the nature (Panchabhutas) and a perfect blend of ancient architectural practices and modern technological innovations. Green Building Design provides an integrated approach considering life cycle impacts of the resources used in Built Environment.

III. ISSUES IN GREEN RATING CERTIFICATION PROCESS-RESEARCH SCOPE

The early generations of Green Rated Built Environment (GRBE) have now been occupied for several years in Indian context, and it is time to explore whether these environments are living up to expectations in objective terms. At present, very less is known about occupant's interpretation and understanding about environmental features and Green Rating System of Built Environment occupied by them. Satisfaction of occupants is related to interpretation and understanding of occupants about how GRBE works [Hua, et. al. 2014]. The pace at which this Green Rating initiative has touched sustainability of Built Environment is under questioned. This is because of its deviation from rate of development of Real Estate Sector in Indian context especially within Warm and Humid Climate Zone. This zone of Indian climate is under influence of this technology as IEQ is a major factor dictating occupants' satisfaction in GRBE. Most of the present practices adopted so far have given least priority to collect continuous feedback of occupants for further improvisation in this sustainability mechanism. Post Occupancy Evaluation (POE) of GRBE through perceptions of various stakeholders after its occupation is one of the important approaches to assess intended performance. POE is a process of systematically assessing performance of Built Environment once they built and occupied by its occupant's for considerable duration [Hadjri Karim & Crozier Carl., 2009]. It includes more holistic and process orientated assessment with some of non-technical factors influencing design of Built Environment [Leaman A. and Bordass, W., 2005]. The intention of this research is to set out a new vision for how POE can close the Building Performance Feedback Loop for further improvement in design of GRBE

IV. OBJECTIVES

Following objectives have been achieved in this present research focusing on Performance Assessment of GRBE using POE:

- i) To assess various Green Rating System used for Built Environment
- ii) To identify various Performance Parameters of Green Rated Built Environment
- iii) To apply various methods of POE of GRBE
- iv) To assess Green Rated Built Environment using POE

- v) To give findings and recommendations regarding Improvement in Green Rating System

V. ROLE OF ACCREDITED PROFESSIONALS IN PERFORMANCE ASSESSMENT

An important development in the growth of Green Building initiative in India is the launch of various Green Building Rating Systems by IGBC and GRIHA. These rating systems are voluntary, consensus based, market-driven building programmes. The objective of this research is to improve present Green Building Rating System by understanding issues concerned with post occupancy of these project from Accredited Professional's perspective. These professional's perspective is dominant in present scenario as their perspective governs majority of decisions in implementation of Green Building Rating System. As on May, 2018 more than 4,573 Green Buildings Projects are registered with the IGBC, out of which 1,374 Green Building Projects are certified and fully functional in the country. Accredited Professionals, who accredited by concerned organizations, like as IGBC, execute Green Building Rating System mechanism. At present, 2,965 professionals have been accredited by IGBC [13]. These professionals have been accredited by IGBC through examination based on their expertise on strategies for successfully achieving credits of Green Building Rating System. Accredited Professionals are involved in deciding technology to be implemented for construction, material to be adopted for each credit; and if required, innovation to be done in project at all phases. This clearly means that these professionals are integral part of Project Team from conceptual phase to handing over of project with certification to Project Owner / Promoter. Therefore, as compared to other stakeholders, Accredited Professional is a key person influencing project progress and success. In some projects, they may get involved during Post Occupancy Phase for up-gradation of rating category. So, these professionals play a crucial role in complete project life cycle including conceptualization to maintenance after post occupancy. Therefore, present research focuses on assessment of Green Building Rating System through Accredited Professional's perspective.

VI. METHODOLOGY ADOPTED IN THE RESEARCH

POE required identification of performance parameters which are critical in relation to stakeholders of Green Certification Process and at the same time, these parameters have been awarded credits during a certification process. Considering this, projects awarded highest Green Rating by IGBC and GRIHA and located in Warm and Humid Climatic Zone have identified. Details of credits achieved by these projects under various parameters of the Green Certification Process listed out. Further, their possibility of assessment through POE also ensured. These listed parameters then clubbed under Site Selection (SS), Energy and Atmosphere (EA) and Indoor Environment Quality (IEQ) heads with their respective stakeholders. After this, Opinion Survey of Accredited Professional carried out with an objective of identifying Critical Performance Parameters which assisted in selection of tools for POE of GRBE.

Out of 1544 Accredited Professionals of IGBC [13], about 200 professional working within Warm and Humid Climate Zone shortlisted and Pre-tested Questionnaire sent to them on registered email contacts. Questions in questionnaire framed on their experience of working on Green Rated Projects as compared to

Conventional Projects. Questions addressing various issues concerned with Green Rated Project delivery in its life cycle have been included in it. Questions pertaining to Design / Preconstruction Phase, Construction Phase and Post Occupancy Phase included in questionnaire. Responses collected on seven point Likert Scale and T-test of Statistical Significance implemented to test these responses [Kothari K.C.,2004] Each question accompanied by a hypothesis, which tested for its acceptance and rejection. A null hypothesis formulated to test its acceptance. Performance Parameters, such as, Occupants Comfort, Indoor Environmental Quality (IEQ), Site Selection and Energy Efficiency (EE) are identified for carrying POE of GRBE.

Procedure Followed in Post Occupancy Evaluation

Based on above identified Critical Performance Parameters and objective of the research, relevant tools under Investigative Post Occupancy Method applied. Tools included under this method are Questionnaire Survey for Occupants as Perception Tool, Direct Measurements of IEQ Parameters as Monitoring Tool and Historical Data Collection of Energy Consumption as an Observational Tool. After this, Green Rated Projects located in Warm and Humid Climate Zone in around Pune city and occupied for more than two years identified to conduct POE. Further, identified projects shortlisted representing both active and passive comfort system and mainly having non-residential use. Permission sought from these shortlisted projects to conduct POE, however, only seven projects gave their consent for conducting it. Out of these seven projects, three projects have been certified by IGBC and four projects have been certified by GRIHA. Three out of seven projects are Naturally Ventilated (Project-1, Project-3 and Project-7), two are fully Air-Conditioned (Project-4 and Project-6) and remaining two are Mixed Mode ventilation category (Project-2 and Project-5).

a) Questionnaire Survey for Occupants as Perception Tool

The objective of present research is to examine satisfaction of occupants of Green Rated Built Environment in overall terms. Questionnaire prepared based on above identified parameters and survey conducted following Random Stratified Sampling Method. While administering survey, equal considerations have given to all occupants and to all floors of identified projects. Occupants representing various functional areas of respective buildings and representing gender, occupation, tenure are selected. Further, they have been stratified based on length of occupancy and location of floor in identified projects. Questionnaire Survey consist of questions concerned to building location, circulation, convenience of occupants within project, comfort and satisfaction of occupants with respect to project as a work space. A null hypothesis is formulated based on Mode of a response to each question. Test of Significance is performed on each question with varying degree of freedom for each individual project.

b) Direct Measurements of IEQ Parameters as Monitoring Tool

Second investigative tool used for POE is direct measurement of IEQ parameters namely Indoor Operative Temperature, Relative Humidity, Carbon Dioxide Level, Air Movement, Illumination Levels as mentioned in Green Rating Systems. These measurements carried out using Data Logger Instrument recording above identified parameters by attaching relevant probes. Floor plans of each building studied and locations identified for IEQ measurements such that overall built up space is covered for IEQ measurement. Schedule of monitoring is based on model developed by Abushakra et al. [2] Short-term Measurement to predict Long-term Predictions (SMLP). Hourly variations are monitored by recording three observations in a day representing morning, afternoon and evening working hours. Outdoor temperature data for last five years (2013-17) collected from meteorological source for identifying yearly climatic variations. [26]

c) Historical Data Collection of Energy Consumption as an Observational Tool

Third tool utilized as a part of Observational Category is collection of energy consumption records for identified projects. Accordingly, energy consumption records for a year collected and analyzed using Energy Performance Index (EPI) prescribed by Bureau of Energy Efficiency (BEE). EPI is representing ratio of energy consumed in a year's period and Built-up Area of projects. BEE Star Rating Program provided with benchmark for EPI Score separately for each climatic zone of India [4]. EPI score is separately provided in two categories, project where less than 50% built area Air-Conditioned and projects with more than 50% built up area Air-Conditioned. Performance of projects under research has been verified based on energy data shared by their owner / occupants and certification agency.

VII. FINDING BASED ON POST OCCUPANCY EVALUATION

POE of GRBE is presently in early stages of its implementation in India. Very few literatures are available on Performance Assessment of GRBE using POE in Indian context. Performance Assessment of identified projects carried out under Investigative Post Occupancy Method as per the methodology mentioned above. Tools included under this method are Questionnaire Survey for Occupants as a Perception Tool, Direct Measurements of IEQ Parameters as a Monitoring Tool and Historical Data Collection of Energy Consumption as an Observational Tool. Tools wise finding of POE of identified projects are mentioned below.

Finding Based on Questionnaire Survey for Occupants

As discussed earlier, occupants are key stakeholder in Performance Assessment of GRBE using POE. The objective of present research is to examine satisfaction of occupants of Green Rated Built Environment in overall terms. One of the ways to engage occupants in POE of project is to interact with occupants in frequent schedule. Questionnaire Survey of occupants contributes significantly in comparative research of project performance. This is to understand occupant's feedback about the project from perspective of sustainability of green strategy. Occupant's survey conducted of identified projects in present research resulted into following set of observations:

- i) Three projects under Performance Assessment are GRIHA certified and Naturally Ventilated ((Project-1, Project-3 and Project-7)) Built Environment. Occupants of these projects are found to be satisfied in thermal comfort, visual comfort and their control over lighting and ventilation systems. These are being government projects, occupants surveyed represents various socio-economic groups.
- ii) Occupants of two IGBC certified and Air-Conditioned (Project-4 and Project-6) projects are satisfied in thermal comfort, however, their response over visual comfort and control over the Heating Ventilation and Air Conditioning (HVAC) system is not satisfactory as compared to NV projects. These projects being corporate offices, occupants surveyed represents particular socio-economic group. This factor is an important factor responsible in perception of occupants about thermal comfort and control over ventilation and lighting systems of Green Rated Projects.
- iii) Mixed Mode (Project-2 and Project-5) projects provide flexibility in adapting to thermal satisfaction for socio-economically diversified occupants. Analysis of occupant satisfaction of MM project of Public Building and Corporate Office Building revealed flexibility in adapting to thermal satisfaction.
- iv) Site selection and availability of transit facility to reach project site is also a major contributor in overall satisfaction of occupants. Occupants from one GRIHA certified project and two IGBC certified projects found dissatisfied about site location during analysis of survey.
- v) Climate Responsive-Energy Efficient Building Envelope Design is one of greener strategy for Warm and Humid Climate Zone in Indian context.
- vi) Occupants of IGBC certified Air Conditioned (Project-4 and Project-6) projects expressed their dissatisfaction about non-availability of natural light due to provision of tinted glass façade on three sides of project building. Whereas, occupants of GRIHA certified MM/NV projects satisfied about availability of natural light.
- vii) Provision of appropriate Window to Wall Ratio (WWR) with glass of acceptable Visual Light Transmittance (VLT) for envelope design [4] is useful to satisfy occupants with reference to visual and thermal comfort.

Finding Based on Direct Measurements of IEQ Parameters

National Building Code (NBC) of India (2016) is now incorporated with Adaptive Comfort Models for Indian buildings, which provides guidelines and range of minimum and maximum values of IEQ parameters for different climatic zones of India. This model is based on the concept of outdoor climate influence indoor comfort of occupants because human can adapt to different temperatures during different times of the year. IEQ parameters measured are compared with provisions given in Chapter 11 – Approach to Sustainability in NBC and other allied standard requirement of Warm and Humid Climate Zone. [16].

Findings from Thermal Comfort Parameters (indoor temperature, relative humidity and air velocity)

- i) Average values of Indoor Operative Temperature for two climatic seasons indicate that MM projects are complying within range of adaptive comfort model of NBC-2016 as compared NV and AC projects. This

compliance is highest in morning readings while failed to comply in afternoon readings and again satisfies in evening session of a working day.

- ii) IEQ compliance also depends on site selection of a project and its planning of open spaces. This is demonstrated by an observation within two projects of MM category in which Project-2 is a public project and Project-5 is a corporate head office of a private organization. Project-2 is situated in interior of a city surrounded by dense tall trees. Each functional space of Project-2 is provided with aspect of surrounding and large central open to sky. Natural Ventilation system is in operation during majority of time in Project-2. On other hand Project-5 is located in industrial area along a National Highway surrounded by hard paved area for parking. Most of functional units of Project-5 are grouped close together and hence Central Active Ventilation System dominates Natural Ventilation in majority of its working hours. It is observed that Project-2 is consistently compliant in November and March months, while Project-5 requires Air-Conditioning to achieve comfort during March month.
- iii) IEQ compliance of NV project is governed by height of structure and planning of a building and its surrounding open space with research of natural conditions of topography and resource availability. This is illustrated with an observation of Project-1 which is a Naturally Ventilated Built Environment and it is ground plus four storied structure located at interior of a city. This project is surrounded by dense planted vegetation. This has direct impact in lowering the surrounding temperature (urban heat island effect). Project-7 is ground plus six storied structure located in interior of a city area surrounded by paved parking and open space. Project-3 is another NV project located in remote village with scarcity of water for growth of vegetative cover in surroundings of project. IEQ compliance is 100% for Project-1 while about 85 % for Project 3 and 97% for Project-7.
- iv) Relative Humidity (RH) values in AC projects are lesser compliant for summer as compare to winter observations. MM project on other hand are having more compliance in humidity in the month of March as well as November. While observations of RH in NV project indicate that a satisfactory air movement in summer and winter contributed in complying humidity levels. Hence orientation of NV green rated projects is important as compared to projects with active system of ventilation.

Findings from Air Quality (Carbon dioxide)

- i) Carbon Dioxide content in most of readings in all types of projects is maintained reasonably within limit of 1,000 PPM specified by standards provisions. Air Conditioned spaces are witnessed with relatively higher amount of Carbon Dioxide values.

Findings from Visual Comfort Parameters (Illumination)

- i) Visual Comfort of the projects is examined through Illumination measured in Lux. NBC specifies 300 Lux as minimum illumination for working hour activities of office buildings.

- ii) NV projects are checked under condition of inactive artificial illumination during working hours. About 25% of values are complying with 300 Lux thresholds for Project-1 while Project-3 is 55% compliant to illumination. Whereas, Project-7 is tallest of the three NV projects found to comply 70% illumination levels.
- iii) Comparison of strategies for lighting indicate that Project-1 is fitted with double glazing for windows shaded by tall trees and longer spans of internal rooms are reasons of decrease in natural light.
- iv) On the other hand, Project-3 is open to sky from all sides with smaller span rooms hence obstruction free sunlight reaches maximum interior space. Illumination compliance level drop down in evening period for Project-1 as compare to Project-3.

Finding Based on Historical Data of Energy Consumption

Energy Efficiency of green rated project is a major performance indicator. BEE Star Rating Program is considered for benchmarking performance of green building. Energy Efficiency finding based on Historical Data of Energy Consumption are as follows:

- i) Electricity meter bill records of four GRIHA certified projects under POE research indicate that EPI score is complying with Five-Star Rating of BEE Star Rating Program.
- ii) Energy consumption data available from IGBC records of identified projects located in Warm and Humid Climate Zone reveals that many projects from MM category failed to achieve Single Star Level of EPI Score of BEE Star Rating Program which is least expected EPI Score.
- iii) Two out of five Commercial Office Projects under MM category failed to achieve Single Star Level of EPI Score of BEE Star Rating Program, whereas, remaining three projects managed to achieve Two Star of BEE Star Rating Program.

GRIHA certified projects under present research have received certification in year 2013-14. Recently in 2017, GRIHA have incorporated POE of their project as a criterion while awarding final certification. Since then most of projects registered under GRIHA are still under pre-certification stage. They are required to produce necessary POE data showing compliance for final award of Green certification.

VIII. CONCLUSION

Present research carried out Performance Assessment of identified projects from Warm and Humid Climate Zone using POE. This research demonstrates POE is most important tool used for Performance Assessment of GRBE after brought under use. Credits analysis of Green Rated Projects by IGBC and GRIHA from Warm and Humid Climate Zone helped in identification of parameters mainly contributing towards credits award and identification of concerned stakeholders for carrying out POE. Opinion Survey of Accredited Professional culminated into short listing of Critical Performance Parameters and selection of appropriate tools used for carrying out POE. Performance Assessment of Green Rated Project through Accredited Professional's perspective is useful to understand issues concerned with Green Rating System within all phases of project life cycle. It will assist in improving present Green

Building Rating System implementation during project occupancy phase by completing the Building Performance Feedback Loop to achieve sustainability objectives. POE of identified projects contributed into identification of performance issues based on their modes. Identified issues include - AC projects are creating major challenges in maintaining balance between IEQ and Energy Efficiency. At the same time, NV projects need to be designed for outdoor climate and their dynamic requirements. The present research reveals adoption of passive ventilation system as a green strategy proves to be sustainable and reliable from occupant's satisfaction perspective. Occupant's satisfactions of similar projects need to be considered as a base for designing future green projects. If green projects adopted with Active Ventilation in the form of HVAC system, then energy metering at more than one functional location is necessary for tracking energy consumption for accurate post occupancy monitoring. Present research emphasizes a fact that POE is not only required for Green Rated Projects but also on normal structure applying for Occupancy Certificate and this certification need to be reviewed periodically. This type of mechanism will create a framework of NBC compliance in objective to achieve sustainability amongst project authorities. A comprehensive climate specific and project use based post occupancy research will create a pool of data base. This data base will assist in designing and adopting a specific design strategy to achieve measurable output based on success story of other project of similar attributes. Incentives given to projects by government authorities based on green certification will be monitored through POE database.

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AUTHORS PROFILE



Dr. S.G. Sonar, PhD, Associate Professor, Department of Civil Engineering, College of Engineering Pune. Email ID: sgs.civil@coep.ac.in



Mr. R.V. Nalawade, M.tech, Research Scholar, Department of Civil Engineering, College of Engineering Pune. Email ID: rohanmtech@gmail.com