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Assessment of Occupant's Satisfaction From Green Rated Built Environment In Indian Context

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ABSTRACT

Green Rating Certification is one of the important mechanisms 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. Occupants of Green Rated Built Environment are crucial and are involved in daily operational activities of them. Therefore, present research focuses on assessment of Green Rated Built Environment performance through their occupant's perspective. Hot and Humid Climatic Zone representing major geographical region of India has chosen for present research. Post Occupancy Evaluation of Green Rated Built Environment is required to assess overall satisfaction of its occupants as a whole. Green Rating Certification systems developed worldwide incorporate energy and Indoor Environmental Quality as important criterions for Post Occupancy Evaluation. In present research, five Green Rated Commercial Buildings have selected for Post Occupancy Evaluation. Out of these five buildings, Indian Green Building Council (IGBC) has rated three buildings and Green Rating for Integrated Habitat Assessment (GRIHA) has rated remaining two buildings. Questionnaire Survey and physical measurement of Indoor Environmental Quality parameters selected as a tool to measure occupant's satisfaction. Test of Significance performed on Questionnaire Survey responses from each building. Hypothesis Testing for each questions revealed level of satisfaction of occupants from Green Rated Built Environment. On the other hand, short-term measurement of Indoor Environmental Quality parameters resulted in complex interpretations.

KEYWORDS: Green Rated Built Environment, Occupants Satisfaction, Questionnaire Survey, Indoor Environmental Quality

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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 is believed to describe the interdisciplinary field that addresses the 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. The manufacturing, design, construction, and operation of Built Environment in which human live and work are 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 design of energy efficient, reducing dependency on fossil fuels, and reduction in air and water pollution in design considerations. This achieved by improving the design consideration of Built Environment to reduce resource use while maintaining a better Indoor Environmental Quality. Increasing awareness and rising social responsibility on part of its stakeholders, has resulted into adoption of Green Rating initiative in Built Environment for achieving sustainability. Green Rating initiative is one of the mechanisms of improving efficiency with which Built Environment consume energy, water, and other natural resources, and reducing 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.

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 Programmes, Certification Services and Green Building Training Programmes, etc. The council is committee-based, member-driven and consensus-focused. 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 Green Rating System based on the five elements of the nature 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.

ISSUES IN GREEN RATING CERTIFICATION PROCESS

Sustainability assessment of Built Environment with reference to Green Rating initiative was emerged in 1990's from United Kingdom. The early generations of Green Rated Built Environment have now been occupied for several years, 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 Green Rated Built Environment works[1]. The pace at which this Green Rating initiative has touched sustainability of Built Environment 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. This zone of Indian climate is under influence of this technology as Indoor Environmental Quality is a major factor dictating occupants' satisfaction in Green Rated Built Environment. Most of the present practices adopted so far have given least priority to collect continuous feedback of occupants for further improvement in this sustainability mechanism. Post Occupancy Evaluation of Green Rated Built Environment and perceptions of various stakeholders after its occupation is one of the important approaches to ascertain intended performance. Post Occupancy Evaluation is a process of systemically assessing performance of Built Environment once they built and occupied by its occupant's for considerable duration. It includes more holistic and process orientated assessment with some of non-technical factors influencing design of Built Environment. Presently, many researchers are focusing on effectiveness of Green Rated Built Environment delivery mechanism and removing barriers in Green Rating Certification process. Jian Zuo[2] in his research has contributed by identifying future research areas of Green Rated Built Environment. He stressed out a fact that Social and Economic Sustainability largely overlooked and assessment of performance of Green Rated Built Environment is missing link in most of researches. Olivia & Christopher[3] studied performance assessment method and its selection process for a Green Rated Built Environment. Author emphasized that occupant centric monitoring methods will benefit

in long life improvement. Also expected results of performance related parameters are far more different than measured one in case of specially energy utilization. In addition, Gupta & Chandilwala[4] pointed that for new technologies, feedback to designers is necessary so to evaluate the learning process, the adaptation and the impact of the user with respect to the new technology. This type of investigation has proven useful in renovation projects. Göçer[5] reviewed existing studies to understand the possible reasons for the missing link of "Building Performance Feedback". Bordass & Leaman[6] explained about learning from experience is one of Post Occupancy Evaluation Technique which includes techniques that get people together to discuss what they are about to do, what they are doing or what they have done. It includes the learning from experience, workshops and / or interviews. Qian Shi[7] carries a critical analysis in his study; author identified critical indicators contributing to conflict between various objectives of Green Rated Built Environment. Author's practical point of view proposes some suggestions while implementing Green Rating Certification process. The intention of this research is to set out a new vision for how future Post Occupancy Evaluation can close the Building Performance Feedback Loop for further improvement in design of Green Rated Built Environment.

OBJECTIVE AND METHODOLOGY

The objective of present research is to examine satisfaction of occupants of Green Rated Built Environment in overall terms. Post Occupancy Evaluation (POE) of Green Rated Built Environment is presently in early stages of its implementation in India. Very few literatures are available on POE on Built Environment in Indian context. In earlier part of this research, researchers identified parameters influencing POE, which include Indoor Environmental Quality as one of the important parameter influencing it. In this research, five Green Rated Commercial Buildings identified representing Hot and Humid Climatic Zone of India for Post Occupancy Evaluation. Out of these five buildings, Indian Green Building Council (IGBC) has rated three buildings and Green Rating for Integrated Habitat Assessment (GRIHA) has rated remaining two buildings. Buildings identified such that they represent both active and passive comfort system. Out of identified buildings, one building is fully Air-Conditioned (AC); two are Mixed Mode (MM) type while remaining two buildings are Naturally Ventilated (NV) Built Environment. Literature Review on POE study executed worldwide revealed consistent use of two investigative tools for predicting performance of Green Rated Built Environment with respect to Indoor Environment Quality. A Built Environment Satisfaction Survey includes questions on occupant's experience on workspace satisfaction, thermal comfort within Green Rated Built Environment, their behavior and organizational approach. Comfort related questions are set on Likert Scale from one to seven, where, 'one' is being Not Satisfactory and 'seven' is being Very Satisfactory. Second investigation conducted by spot measurements of

parameters, such as, Indoor Temperature, Relative Humidity, Carbon Dioxide Levels, Illumination, and Air Movement. Floor plans of each building are studied and same locations identified for measurements, which pointed out by occupants during Questionnaire Survey. Duration, day, and month of year identified based on model developed by Abushakra[8] for Short-term Measurement to predict Long-term Performance (SMLP). Three readings for each parameter throughout the day representing morning, afternoon and evening working conditions had recorded by Testo-435 instrument. Results of both tools compared and analyzed to predict Green Rated Built Environment's relative performance.

BUILDINGS

In present research, five Green Rated Commercial Buildings from Hot and Humid Climatic Zone of India selected for Post Occupancy Evaluation. Out of these five buildings, Indian Green Building Council (IGBC) has rated two buildings and Green Rating for Integrated Habitat Assessment (GRIHA) has rated remaining three buildings. Out of identified buildings, one building is fully Air-Conditioned (AC); two are Mixed Mode (MM) type while remaining two buildings are Naturally Ventilated (NV) Built Environment.

Table No. 1 Salient features of green rated buildings selected for study

	Building 1	**Building 2**	**Building 3**	**Building 4**	**Building 5**
Rating award	IGBC Platinum 2013	GRIHA 5 Star rated 2013	GRIHA 4 Star rated 2014	GRIHA 4 Star rated 2014	IGBC Gold rating 2015
Site Area(Sqm)	15570	7547	263046	9584.24	20800
Built Up Area(Sqm)	12000	7912	17250	4886.90	11800
Air conditioned	90%	15%	2.4%	2629.93	27.44
Occupants	500	56	400 students and 68 Staff	24 staff and 50 Guests	128
Energy targets claimed during Award of rating	50 % energy saving	35kWh/ m2/year	12.3KWh/ m2/year	89.16KWh/m2 /year	45% energy saving
Special features	Energy generation is on solar panels only 2.6% energy consumption from grid	30 kW of Solar PV and 10 kW of BIPV	Onsite renewable energy 14 KW	solar PV installed on site is 22 KW	

QUESTIONNAIRE SURVEY

The objective of this research is to improve present Green Rating System by understanding issues concerned with Green Rated Built Environment delivery in its life cycle from occupants' perspective. Their perspective governs majority of decisions in successful implementation of Green Rating System. Occupants from selected Green Rated Commercial Buildings considered for conducting research through Pre-tested Questionnaire Survey. Pre-tested Questionnaire survey administered through Stratified Random Sampling technique. Questions addressing various issues

concerned with Green Rated Built Environment delivery in its life cycle have been included in questionnaire. Occupants representing various functional areas of respective buildings and representing gender, occupation, tenure selected. Total 85 responses from all five identified buildings surveyed. Questionnaire Survey consist of questions concerned to building location, circulation, convenience of occupants within Green Rated Built Environment, comfort and satisfaction of occupants with respect to building as a work space. Responses collected on seven points Likert Scale as presented in Table 2. Likert Scale utilized where 'one' represents Not Satisfied and 'seven' represents Very Satisfied. Test of Significance performed on each question with varying degree of freedom for each individual building (Kothari,2004). Table 2 and Table 3 represents summary of Test of Significance on responses received to questionnaire survey. Test of Significance is performed by considering MODE as a measure of Central Tendency. The confidence level of 99% is reflecting 1% significance level. Confidence level indicates the likelihood that the answer will fall within that range, and the significance level indicates the likelihood that the answer will fall outside that range**.** Modal value of answer framed into a Null Hypothesis. Student's 't' distribution is used for sampling distribution. When population Standard Deviation is not known and the sample is of a small size (i.e., $n < 30$), we use 't' distribution for the sampling distribution of Central Tendency and workout 't' variable as given below. If this calculated "t" is greater than value of "T" from distribution table, then Null Hypothesis formed for each question is rejected and vice versa. (Table 2 and Table 3)

Table 2 Summary of responses of questionnaire survey

		LIKERT Scale Mode value (μ0)				
		Buildings				
Sr No	**Questions**	**1**	**2**	**3**	**4**	**5**
1	How satisfied are you, in overall terms, with building as a place of work?	6	7	7	7	6
2	Are you satisfied with building location, public transportation, time of travel to reach building?	5	7	1	7	2
3	How accessible is the building from the road i.e.reception door?	6	7	6	7	6
4	How easy is to move between floors i.e. Vertical circulation?	7	7	7	7	6
5	How easy is to move within floor i.e. Horizontal circulation?	7	7	7	7	7
6	Does the quality of air at this location of building have a negative effect on your work performance?	7	7	7	7	7
7	Is the air humid or dry?	4	4	4	4	4
8	Is there air movement?	4	7	7	3	4
9	Do you have control over ventilation?	1	7	7	6	5
10	Does the Temperature in this part of building have a negative effect on your work performance?	7	7	7	7	7
11	Is the temperature in summer comfortable?	7	4	3	4	6
12	Is the temperature in Winter comfortable?	7	7	7	6	6
13	Do you have control over temperature?	7	1	1	1	1
14	Does the light in this part of building have a negative effect on your work performance?	7	7	7	7	7
15	Is there too much or too little natural light?	4	4	4	4	1
16	Is there too much of glare from natural /Sunlight?	7	2	7	7	7
17	17. Do you have control over artificial lighting?	7	7	7	7	7
18	18. Are you satisfied with sound insulation and acoustics of building units?	6	7	7	7	6

Table 3 Summary of test of significance for each questions

		T value from t distribution table for α=0.01 and df				
		2.508 and 22	2.583 and 16	2.479 and 25	2.821 and 9	2.650 and 13
		If Calculated t< T from table, accept Hypothesis)				
Question no.		Building 1	Building 2	Building 3	Building 4	Building 5
1	Calculated t Value	0.19	-0.47	-0.32	-0.21	0.04
	Hypothesis	satisfied	satisfied	satisfied	satisfied	satisfied
2	Calculated t Value	0.20	-0.44	0.12	-0.21	0.88
	Hypothesis	satisfied	very satisfied	not satisfied	very satisfied	not satisfied (partially)
3	Calculated t Value	0.04	0.00	-0.12	-0.21	-0.46
	Hypothesis	easily accessible	easily accessible	easily accessible	easily accessible	easily accessible
4	Calculated t Value	-0.35	0.00	0.00	0.00	0.54
	Hypothesis	very easy	very easy	very easy	very easy	very easy
5	Calculated t Value	-0.35	0.00	0.00	0.00	-0.48
	Hypothesis	very easy	very easy	very easy	very easy	very easy
6	Calculated t Value	-0.49	0.00	-0.35	-0.46	-0.68
	Hypothesis	not significant	not significant	not significant	not significant	not significant
7	Calculated t Value	0.05	0.54	0.06	-0.34	0.00
	Hypothesis	neutral	neutral	Neutral	neutral	neutral
8	Calculated t Value	0.38	-0.19	-0.07	0.71	-0.31
	Hypothesis	neutral	good	Good	less	neutral
9	Calculated t Value	1.26	-0.37	-0.21	-0.49	-0.04
	Hypothesis	no control	full control	full control	part control	part control
10	Calculated t Value	0.45	0.14	0.16	0.54	0.12
	Hypothesis	not significant	not significant	not significant	not significant	not significant
11	Calculated t Value	-0.84	0.53	0.54	0.28	-0.31
	Hypothesis	very comfortable	neutral	not comfortable	neutral	comfortable
12	Calculated t Value	-0.86	0.00	-0.13	-0.51	-0.31
	Hypothesis	comfortable	comfortable	comfortable	comfortable	comfortable
13	Calculated t Value	-1.03	0.84	0.00	0.66	0.05
	Hypothesis	full control	no control	no control	no control	no control
14	Calculated t Value	-0.73	-0.31	0.00	0.00	-0.38
	Hypothesis	not significant	not significant	not significant	not significant	not significant
15	Calculated t Value	0.49	0.29	-0.28	-0.11	0.24
	Hypothesis	neutral	neutral	Neutral	neutral	not significant sunlight
16	Calculated t	-0.81	-0.77	-0.69	-1.08	-0.95

		T value from t distribution table for α=0.01 and df				
		2.508 and 22	2.583 and 16	2.479 and 25	2.821 and 9	2.650 and 13
		If Calculated t< T from table, accept Hypothesis)				
	Value					
	Hypothesis	Sunlight glare is not significant	Sunlight glare is significant	Sunlight glare is not significant	Sunlight glare is not significant	Sunlight glare is not significant
17	Calculated t Value	-0.75	-0.25	-0.14	0.00	-1.20
	Hypothesis	full control	full control	full control	full control	full control
18	Calculated t Value	-0.60	-0.12	-0.23	0.05	0.08
	Hypothesis	satisfied	satisfied	satisfied	satisfied	satisfied

MEASUREMENT OF IEQ PARAMETERS

In support of results of Questionnaire Survey, physical measurement of Indoor Environmental Quality parameters carried out using Testo-435 Instrument. Short-term Monitoring for Long-term Performance approach (SMLP) has used for this data collection. Abushakra[8] developed a procedure for selecting period of the year that has the widest range of dry bulb temperature and humidity ratio while capturing the yearly mean of these two variables. The same algorithm has applied for monthly time intervals to determine the best month of the year when in-situ monitoring is likely to yield most accurate in its long-term predictions. Whether data for 2013-2017 for Pune location is collected[10] and SMLP model implemented on temperature data. Normalized average error for each month is calculated and shown in Table 4.0. Month of November is representing least error and hence chosen for data collection.

Table 4 Average normalised error for each month daily temperature

SI. No.	2013-2017	Average	SI. No.	2013-2017	Average
1	AEi January	0.133888	7	AEi July	0.934595
2	AEi February	0.054638	8	AEi August	0.832366
3	AEi March	0.336417	9	AEi September	0.478233
4	AEi April	0.512265	10	AEi October	0.200262
5	AEi May	0.500086	11	**AEi November**	**0.034471**
6	AEi June	0.396565	12	AEi December	0.360205

Floor plans of each building studied for deciding locations for spot measurements and crosschecked with locations pointed by respective occupants of buildings. In month of November, representing least error, continuous monitoring for five days carried out in identified buildings at pointed locations. Indoor Environmental Quality parameters, such as, measurement of Indoor Temperature, Relative Humidity, Air Velocity, Carbon Dioxide Concentration and Illumination Level recorded using Testo-435 Instrument. Three readings for each parameter throughout the day representing morning, afternoon and evening working conditions had recorded. Average of five days recorded measurements compiled for all Indoor Environmental Quality parameters and analyzed to predict Green Rated Built Environment's relative performance.

Table 5 Summary of IEQ data for building 1

Floor	Area description	Indoor temperature (degree Celsius)	Relative Humidity(%)	Air velocity (m/s)	CO2 (PPM)	illumination (Lux)
First Floor	Model room	25.4	38.2	0.8	420	180
		28.1	36.5	0.4	606	155
		27.4	34	0.5	575	210
	Laboratory	27.5	38.4	0.6	490	530
		28.8	37.5	0.4	530	167
		29.5	38.1	0	567	210
	Seminar (AC)	26.6	52.4	N.A.	564	210-380
		27.2	51.9		524	
		27	52.7		569	
Second floor	Account Section	25.4	37.1	0.7	602	230
		26.1	35.2	0.6	425	265
		25.8	38.4	0.7	610	227
	Reading Hall	27.9	37.2	1	568	150-320
		28.2	39.1	0.9	530	120-300
		28	40.2	1.1	579	120-315
	Stack area	27.9	37.2	1	515	175-250
		28	39	0.9	465	160-260
		28	37.5	1.1	425	165-240
Third Floor	Conference Hall (AC)	29.2	36.2		440	300
		29	35.2		510	420
		29	35.2		515	400
	Computer Class	27.2	37.1	0.7	536	250
		28.9	39.1	0.9	580	255
		29	37	0.7	530	250
	South side Claas rooms(2 No)	28.2	37.2	0.4	572	276
		29.5	39.2	0.5	482	269
		28.5	36.2	0.4	475	270
	South west classroom	28.5	38.1	0.5	530	300
		29.2	39.2	0.4	512	320
		29.1	36.2	0.5	567	300
	West side Class room	27.2	37.5	0.5	580	250
		27.1	37	0.3	420	270
		27.5	37.7	0.4	410	290
Fourth Floor	Directors Chamber (AC)	27	30	NA	357	320
		27	32		430	320
		27.2	35		450	300
	Committee Hall	27.4	28.4	0.7	430	350
		29.2	28	1.1	450	340
		27.2	29	1.1	490	370
	Officers and administrative Cabins	28.1	37.4	0.5	478	270
		29.2	39	0.7	492	285
		27.5	35	0.5	525	279

Table 6 Summary of IEQ data for building 2

Floor	Area description	Indoor temp. degree Celsius	Relative Humidity(%)	Air velocity (m/s)	CO2 (PPM)	illumination (Lux)
Ground	reception General	27.2	64	0.4	441	172-352
		28.3	60	0.4	465	200-450
		27.5	56	0.6	480	180-387
	VIP entry and waiting	26	68.5	0.5	493	95-452
		25.7	71.2	0.2	454	80-120
		26.2	70.7	0.4	478	110-326
	Class-I suites	25.4	70.8	NA	625	132-40
		25	71.2		445	150-270-70
		26.2	70.6		530	147-160
	Class-II suites	25	73		415	230-275
		25.2	72.8		421	270
		26.3	73.5		450	247
	Dining	25.6	68.2	1.8	670	74-150
		26.4	65.4	1.2	598	80-180
		25.3	70.3	0.8	576	67-212
First Floor	Conference	26.2	68.4		754	280
		28.4	71.5		571	290
		26.8	67.2		587	280
	DCM Suites	26	45.5		557	258
		25.7	45.2		571	271
		24.1	45.3		580	268
	PA Suites	25.2	51.5		468	210
		23.7	52.3		466	225
		24.6	50.2		478	256
	Class I Suites	24.7	71.4		495	150-75
		25.2	70.8		512	85-150
		25.3	67.4		507	147-89
	Class II Suites	25.4	69.5		427	170-65
		25.8	68.7		485	72-171
		26.7	68		497	78-190
Second floor	Conference	24.6	74.4	NA	601	254
		24.5	74.9		556	280
		26.1	75.3		579	257
	DCM Suites	25.4	70.8		625	132-40
		25	71.2		445	150-270-70
		26.2	70.6		530	147-160
	PA Suites	25	73		415	230-275
		25.2	72.8		421	270
		26.3	73.5		450	247
	Class I Suites	26	45.5		557	258
		25.7	45.2		571	271
		24.1	45.3		580	268
	Class II Suites	25.2	51.5		468	210
		25.2	70.8		512	85-150
		25.3	67.4		507	147-89

Table 7 Summary of IEQ data for building 3

Floor	Area description	Indoor temperature (degree Celsius)	Relative Humidity(%)	Air velocity (m/s)	CO2 (PPM)	illumination (Lux)
Main building	reception	27.9	48.5	1.9	435	678
		28.1	57.9	1.7	452	867
		28.3	59.23	0.5	489	680
	Office	30.5	59.4	0.4	595	190
		28.8	54.6	0.4	534	157
		31.5	49.7	0.7	520	147
	Principals Cabin	27	45.7	NA	459	285
		28	42		567	270
		25	40		428	280
	Class room GF	32	57	0.5	590	190
		29	53.5	0	573	175
		30	48.9	0.4	484	124
	Classroom FF	30.2	49.5	0.4	480	130
		29.3	50.6	0.8	529	118
		30.5	52.6	0.6	490	120
guard and weapon store area	second floor	29.8	53.8	0.5	475	145
		30.3	48.9	1.9	555	133
		28.7	53.8	0	434	137
Hospital	Inspection and treatment area	29.3	51.8	0.5	456	410
		30.8	50.8	1.2	530	480
		29.8	52.6	0.9	422	1020
Mess/Canteen	Dining	29.7	52.3	0.5	436	895
		31.9	50.2	1.2	530	506
		31.8	58.3	0.2	589	520
	Kitchen	31.3	52.2	0	721	147
		32.5	56.3	0	645	112
		31	52.1	0	800	46
Residential Quarters	FF	27.8	56.8	0.8	586	324
		30.1	52.1	0.8	844	386
		30.3	59.5	0.6	765	435
Assembly Hall		28.7	52.1	1.2	510	345
		29.6	53.1	1.6	470	280
		29.5	57.6	0.8	525	286

Table 8 Summary of IEQ data for building 4

Floor	Area description	Indoor temperature (degree Celsius)	Relative Humidity(%)	Air velocity (m/s)	CO2 (PPM)	illumination (Lux)
Ground Floor	reception	27.4	42.5	1.2	468	730
		28.3	45.3	0.8	523	810
		27.9	47.5	1.1	567	780
	Visiting cabins	26.2	52.3	0	630	320
		27.2	50.1	0	620	280
		28.4	50.9	0	590	276
	Utility Area	27.6	48.1	NA	620	321
		28.1	42.6		728	280
		26.9	38.5		686	296
	Kitchen	29.2	58.9	0.4	681	250
		27.8	56.29	0.1	592	237
		29.5	57.2	0.4	569	218
	Dining	28.3	53.8	1.2	572	480
		27.5	57.78	0.8	478	475
		27	56.45	1.1	490	469
FIRST FLOOR	Waiting	28.3	54.1	0.4	475	481
		27.4	50.3	0.4	408	433
		28.1	51.28	0.5	432	437
	Conference	26.2	49.21	1.1	514	410
		26.5	45.18	1.2	542	427
		27.4	42.7	0.9	497	396
	Plant Head cabin	26.7	48.2		405	479
		26.8	43.45		487	503
		26.3	47.23		402	510
	Executive Cabin	26.8	42.34		521	486
		26	41.5		530	511
		26.2	46.7		470	460
Second floor	Working Area	27.8	52.9	0.6	582	370
		29.2	53.18	0.8	680	397
		28.7	51.72	0.8	629	364
	Conference and meeting hall	27.8	51.8	0.4	521	420
		28.6	52.1	0.8	530	462
		27.1	54.3	0.6	510	410

Table 9 Summary of IEQ data for building 5

Floor	Area description	Indoor temperature (degree Celsius)	Relative Humidity(%)	Air velocity (m/s)	CO2 (PPM)	illumination (Lux)
Ground Floor	reception	26.3	38.9	1.4	501	754
		28.1	51.7	0.8	555	890
		28.3	56.21	0.5	637	769
	Visiting cabins	27.6	52.1	0.4	522	240
		27.8	54.6	0.6	622	256
		28.2	49.7	0.7	481	239
	Admin wing	26	45.7	NA	649	375
		26	42		496	360
		25	40		500	374
	Maintenance dept.	28.4	57	0.5	497	218
		27.1	53.5	0	618	189
		27.6	48.9	0.4	649	176
	Office head	27.5	49.5	NA	584	324
		27.8	50.6		664	356
		27.4	52.6		510	320
first floor	HR	27.5	53.8	0.5	445	278
		27.2	48.9	0.8	501	260
		27.7	53.8	0	609	321
	Design	26.5	51.8	0.5	550	356
		27.2	50.8	0.8	516	480
		26.2	52.6	0.9	463	380
	IT dept.	26.4	52.3	0.5	602	370
		27.1	50.2	0.4	626	514
		27.7	58.3	0.2	487	520
	Regional head cabins	28.2	52.2	NA	653	459
		26	56.3		586	430
		27.2	52.1		675	450
Second floor	Chairman's cabin	27.8	56.8	NA	487	458
		26.5	52.1		509	436
		26.5	59.5		538	478
	waiting area/ reception	28.7	52.1	0.4	603	345
		27.5	53.1	0.6	590	366
		27.3	57.6	0.4	527	325

ANALYSIS

Questionnaire Survey conducted with occupants of five Green Rated Commercial Buildings analyzed on seven point Likert Scale. For every question, a Null Hypothesis formulated based on Central Tendency (MODE) of responses. Students 't' Test of Significance performed on individual building's responses. Table 2.0 represents calculated "t" value and results of Significance Test for each building on each question. If calculated "t" value is less than "T" value from distribution table,

Hypothesis is accepted. These tested Hypotheses for each question also represented on right side of Table 2.0. Following observations made for each building:

First building is fully Air-Conditioned built space and comfort responses are satisfactory. Air movement is limited within open space and sit out area on ground floor. Air velocity measurement also highlights the concern about lesser air movement fully air-conditioned spaces lacks this attribute as it is also proved during air movement study in other Mixed Mode buildings (Table 5, 8, and 9). Said building is rated satisfied for its overall impact on occupants. Second building is Naturally Ventilated with Window to Wall Ratio provided as per Energy Conservation Building Code 2017[11] requirements. Occupants have responded satisfactory. East-west orientation of building and higher Window to Wall Ratio have resulted in glare of sunlight received during few hours of the day as reported by occupants located at few locations of building. A range of temperature is within adopted comfort range specified for NV type of building (Table 5 and 7). Third building is remotely located from town and hence occupants are not satisfied with Public Transportation Facility as reported in Questionnaire Survey. Summer temperature is also not comfortable which is evident from IEQ data collected in second part of data collection. Fourth building is Mixed Mode type of a building and most of occupied spaces are Air-Conditioned. Building is hardly 50 % occupied throughout year hence lesser number of responses received. This building surrounded by buildings and nearby structures, which have an effect on air movement inside the building occupied spaces. Overall building occupants are fully satisfied. Fifth building is also Mixed Mode type of building with 70 % of space Air-Conditioned. Satisfaction of occupants with reference to its location is less as compare to first, second and fourth building. Building is located in Industrial area. North- south orientation of Building has resulted in lesser sunlight, which reflected in responses of occupants. Indoor temperature of building compared with adaptive comfort temperature ranges prescribed by Energy Conservation Building Code, 2017[11]. Mean outdoor temperature value for month of November for 2013-17 is 23.50 degree Celsius. Ranges of Indoor Temperature for Naturally Ventilated (NV) full Air-Conditioned (AC) and Mixed Mode (MM) calculated and presented in Table 10

Table 10.0 Comfort range of Indoor temperature for building types

Type of Building	Minimum temperature (degree Celsius)	Maximum temperature (degree Celsius)
MM	20.99	27.91
AC	23.58	26.58
NV	23.14	27.9

It observed that Performance of Mixed Mode building is comparatively better than fully Air-Conditioned Buildings. Naturally Ventilated building performance is governed by outdoor exposure as Window to Wall Ratio (WWR) in second building is in compliance with ECBC hence better performance is evident in that. Relative Humidity is satisfactory in Naturally Ventilated second

building as compared to Air-Conditioned buildings. Air movement dominates humidity values hence values of better air movement have shown drop in humidity values in second building. Carbon Dioxide level was found to be moderate in all buildings. Depending on occupancy, density and type of activity, values are fluctuating. For example, in Kitchen of third building Carbon Dioxide values are very high. While it is, lower at third floor and fourth floor of second building. Therefore, IEQ study is significant in Post Occupancy Evaluation and assist in analyzing performance of Green Rated Built Environment through its occupants' perspective.

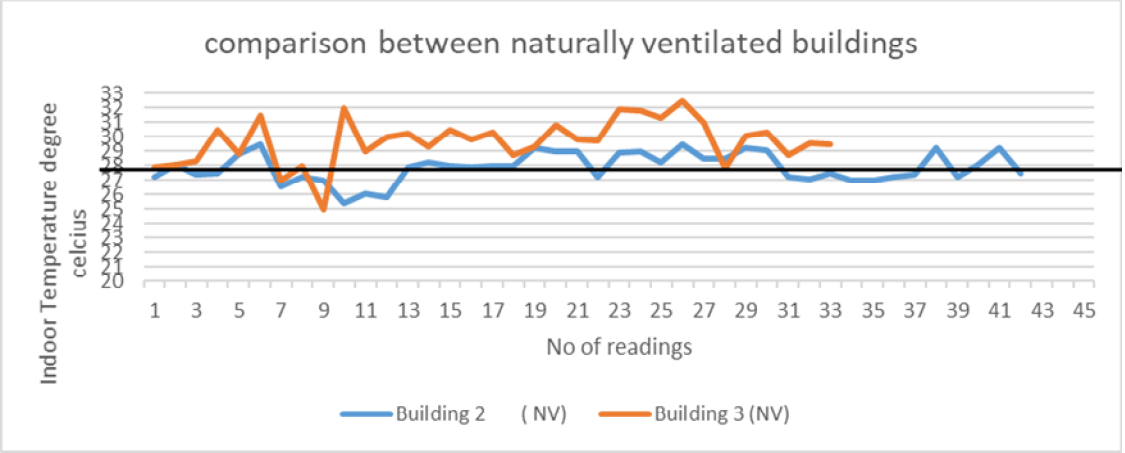

Figure 1 Indoor temperature deviation of NV buildings from maximum adaptive temperature value

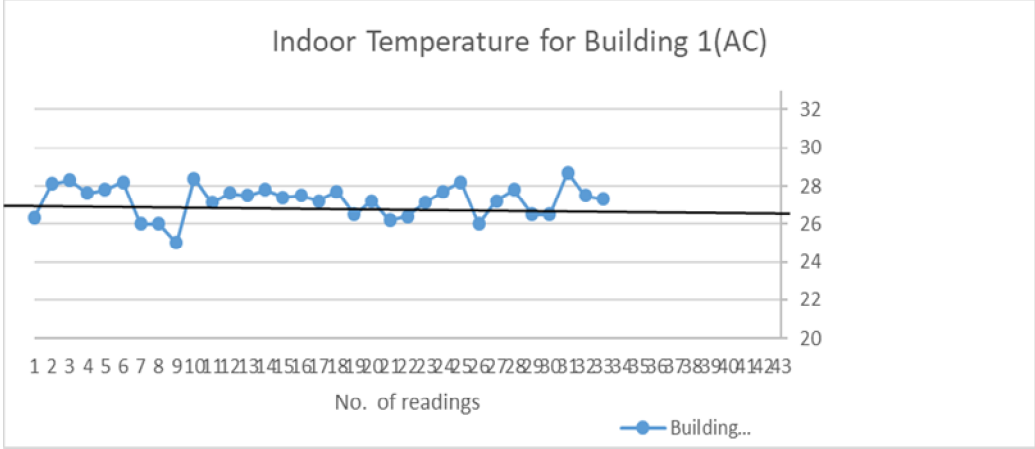

Figure 2 Indoor temperature deviation of AC building from maximum adaptive temperature value

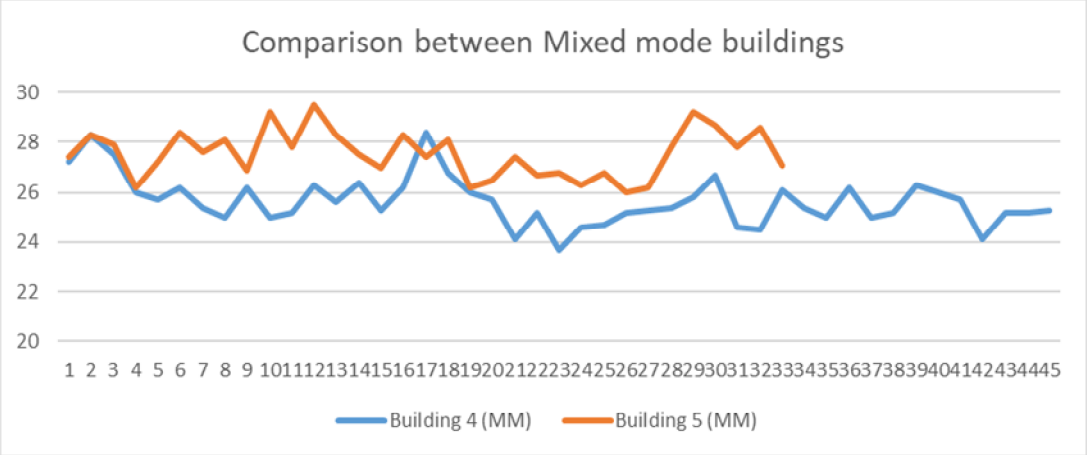

Figure 3 Indoor temperature deviation of MM buildings from maximum adaptive temperature value (27.91)

CONCLUSION

Questionnaire Survey and IEQ parameter measurement are two important tools that contribute significantly in comparative study of building performance in Post Occupancy Evaluation of Green Rated Built Environment. In present research, Questionnaire Survey revealed that occupants are satisfied with respect to building as a workspace in terms of Indoor Environmental Quality. Occupant's survey of Building 3 and 4 reported dissatisfaction regarding its location with respect to its convenience to reach and transit facility Site selection for green building is significant and it depends on closer proximity to nearby city or town and ease of transportation from residence to work location. Questionnaire Survey is followed by measurement of IEQ parameters. Data collected for five days continuous monitoring of Indoor Temperature, Relative Humidity, Air Movement, Carbon Dioxide and Illumination Levels represents that Air-Conditioned building is performing better than Naturally Ventilated building while humidity and carbon dioxide levels and air movement, humidity is relatively satisfactory than Air-Conditioned building. Thus, post occupancy evaluation of Green Rated Built Environment reveals that achieving green rating for a built space creates a platform for sustainable practices. This platform needs frequent validation and used to improve occupant's satisfaction by using appropriate tool. More number of buildings complying post occupancy study will create a national database for formulating guidelines with reference to occupant's perspective.

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