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Post Occupancy Evaluation of IEQ Parameters in Residential Buildings

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POST OCCUPANCY EVALUATION OF IEQ PARAMETERS IN RESIDENTIAL BUILDINGS

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***Abstract*— The post-occupancy evaluation (POE) is a performance assessment of buildings in use that can help property owners and managers better understand how well a facility is working, how its performance compares to similar structures or set benchmarks, and how a building might be improved. A solid grasp of how a building works can explicitly link its actual performance to either new or existing building innovations or remedial measures. While there is a lot of information on POE in commercial buildings, there's not much in the residential sector. In this mini project, it is focussed to assess the satisfaction levels of the occupants and to quantify the IEQ parameters in a residential building. Sample sizes are determined, based on which a detailed questionnaire survey is conducted for the research. The city of Kochi, is the primary location considered due to its vivid factors both geographically and climatically.The project focuses on to identify the resident satisfaction level , quantify the IEQ parameters in a residential building and to suggest remedies if required. The findings and the results are analysed based on different factors. The findings will be useful for the prioritisation of the performance criteria of the buildings.**

Keywords*— *Post occupancy evaluation, IEQ, escalation, buildingIntroduction (Heading 1)

I. INTRODUCTION

Client satisfaction is a significant aspect in the construction process and the development of customer relationships. Customer interactions and delighted consumers are becoming increasingly important as construction companies confront increased competition. Customer satisfaction allows construction companies to set themselves apart from their competitors and gain a long-term competitive edge. Buildings' principal aim is to offer occupants with a conducive, safe, pleasant, healthy, and secure interior environment in which to engage in various activities such as work, study, leisure, and family life, as well as social connections. Buildings are built, planned, constructed, and managed to reach this goal based on standards and specifications defined by governments, professionals, and experts who are believed to have enough knowledge of user needs and expectations. A well-designed building is one that is functional, aesthetic and structurally sound. It is a building that gives more than what has been requested while utilizing limited resources. In comparison to other industries where customer experience is the key driving factor, the requirement for architects/designers to address the end users of their goods (buildings or other facilities) has not been fully realised. Buildings are constructed and managed according to standards and specifications established by the government, professionals, and experts who are supposed to have a thorough understanding of user needs and expectations; however, these standards and specifications do not conform to changing user needs and expectations. As a result, regular performance review, as well as studying and understanding user needs, expectations, and aspirations, can help improve building performance. POE, or Post-Occupancy Evaluation, is one of the most effective approaches for obtaining performance data on existing structures. Post-occupancy evaluation (POE) is a systematic examination of a building's performance during service, generally including but not limited to user perception analysis, for a variety of objectives. The post occupancy evaluation, or POE, is a performance assessment of buildings in use that can help property owners and managers better understand how well a facility is working, how its performance compares to similar structures or set benchmarks, and how a building might be improved. A complete understanding of how a building works can be used to link its actual performance to either new or current building innovations or remedial measures. While there is a wealth of information available regarding the POE of commercial buildings, there is a scarcity of similar, consistent ideas in the residential sector. Therefore, Post occupancy evaluation, as a part of Building performance evaluation has to be carried on a routine basis and as a mandatory check to ensure that the building performances are meeting the satisfaction of the residents.

II. POST OCCUPANCY EVALUATION (POE)

Post occupancy evaluation can simply be defined as the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time. Post Occupancy Evaluations is used to improve the ways that buildings are used to support productivity and wellbeing. Specifically it is used to:

1) Account for building quality

2) Inform planning and briefing (programming) for new buildings and alterations

3) Troubleshoot building/use problems (such as change management and new work styles)

POE incorporate may include quantitative and qualitative techniques. Most POEs will involve seeking feedback from the occupants of the place being evaluated; this may be achieved through various survey methodology including questionnaire, interview or focus group. The occupant feedback may be supplemented by environmental monitoring, such as temperature, noise levels, lighting levels

and indoor air quality. More recently, POEs tend to include sustainable measures such as energy consumption, waste levels, and water usage. Other commonly used quantitative measures include space metrics, for example occupational density, space utilization and tenant efficiency ratio. Cost, either expressed as the cost of the project per square meter or the total cost of occupancy, is considered a key metric in building evaluation and may be compared with the occupant feedback to provide a better understanding of value. Post-occupancy evaluation (POE) constitutes the activities of the BPE process once the building is occupied and in use, focussing on the operational performance and the occupants of the building. It is important to know to what extent the building maintains its occupants' satisfaction and perceived comfort. Post-occupancy evaluation (POE) can be employed as a major part of BPE. This would involve collecting feedback (soft data) from the occupants through survey questionnaires, interviews and / or workshops, ideally at least one year after building occupation to cover at least on seasonal cycle.

III. LITERATURE SURVEY

The papers mentioned above emphasised the importance of occupant's satisfaction in various types of buildings particularly residential, non-residential, commercial, industrial type of building. The building layout, it's features, spaces, comfort, indoor environmental quality parameters like the thermal, visual comfort etc are the prominent attributes assessed. Any building has to be completely assessed for its performances for which the BPE tool was used. Amongst which, the best effective tool to assess the performance post occupation was found to be the Post Occupancy Evaluation or POE surveys. Mostly, the questionnaire survey which has the ratings ranging from very poor to very good was used as a mean of POE survey. The results analysed were mainly useful for the designers, builders and architects as it was helpful for them to determine the utility and quality of the products they delivered or they wanted to deliver. The need of taking into account relevant inputs from end-users or inhabitants of residential developments while planning, designing, and developing satisfying houses is emphasised. However, most of the researches were focused on non-residential buildings. Hence the need of improvement on the quality of the residential units is inevitable and is equally important.

IV. RESEARCH METHODOLOGY

A. Identification of performance attributes

Post Occupancy Evaluation (POE) on the satisfaction levels of the occupants of residential buildings would depend on several criteria's. The primary data collection used to assess the performance of any constructed facility would be the user/occupant input. The main goals of a facility provider are to satisfy the requirements, expectations, and aspirations of users. In order to get the proper input during the building performance evaluation, it becomes required to assess the created facility with regard to matching user demands and expectations. Questionnaire survey was used to assess the post occupancy evaluation. Based on the literature survey, these built facility attributes are identified which was incorporated in the questionnaire survey. These include 4 IEQ parameters which was quantified:

- Thermal comfort
- Acoustic comfort
- Lighting quality
- Indoor air quality.

B. Analysis of Questionnaire

Data obtained from the literature review was used to identify the basic Indoor Environmental Quality parameters (IEQ) which needs to be accounted whilst carrying out the post occupancy evaluation survey of a residential building. It was used to prepare the questionnaire survey which was then distributed amongst the various groups of people who are basically the tenants/occupants residing in the city of kochi. The questionnaire was prepared based on the knowledge obtained from reviewing the literature and from expert advices. The questionnaire survey was conducted the determine the satisfaction levels of the occupants of the residential buildings in kochi. A questionnaire with 20 queries were prepared for the study which included the attributes derived from the literature survey.

The degree of satisfaction levels was included in the questionnaire. The questionnaire was designed to examine the respondent's satisfaction levels in determining the various building attributes which shows or depicts the performance of a building, which is a residential building in this case. The questionnaire survey was conducted by the means of Google forms.

The questionnaire survey was conducted on 103 people and the respective data were collected. Each respondent was required mark the satisfaction levels based on a five point likert scale, ranging from very dissatisfied to very satisfied respectively. Table 3.1 shows the ranges of satisfaction level used in the questionnaire survey

TABLE 1 SATISFACTION LEVEL RANGES USED IN THE QUESTIONNAIRE

Ranges	Numerical Value
Very Dissatisfied	1
Dissatisfied	2
Neutral	3
Satisfied	4
Very Satisfied	5

C. Selection of Sample

As the study focuses on the post occupancy evaluation of residential building's in Kochi, a sample residential building in the city limit was identified and chosen. The selection is based on the parameters that the building is located within the city and the building is a residential building with the

standard facilities. A two storey building with a built up area of 1400 sqft was chosen. Different rooms of the building, including living room, dining room, kitchen and master bedroom were taken for the study.

D. INDOOR ENVIRONMENTAL QUALITY (IEQ) PARAMETERS

Indoor Environmental Quality (IEQ) is most simply described as the conditions inside the building. It includes air quality, but also access to daylight and views, pleasant acoustic conditions, and occupant control over lighting and thermal comfort. It may also include the functional aspects of space such as whether the layout provides easy access to tools and people when needed and whether there is sufficient space for occupants. Building managers and operators can increase the satisfaction of building occupants by considering all of the aspects of IEQ rather than narrowly focusing on temperature or air quality alone.

The Indoor Environmental Quality (IEQ) parameters are generally taken as the thermal comfort, air quality, lighting quality and acoustic comfort. However, in the second phase, these parameters are quantified based on the sample chosen in the main spaces in the structure as to give a trend of performances of these parameters in the building. These are done with the help of mechanical devices including Anemometer , Lux meter, Digital thermometer and sound level meter. Better is the values obtained for the IEQ parameters, better is the performance of the building which it is intended to.

1) Measurement of thermal comfort

Thermal comfort is identified by measuring the temperature in the rooms of the building by the means of digital thermometer. Digital thermometer shows the temperature level in degree Celsius unit. Grids are plotted in the room, where the thermometer is placed at a suitable height and the measurement is taken in the different grid points. The readings are observed and analysed, taking the measurements from each room at different time intervals.

The readings obtained from the thermometer in three different timings in different rooms were found to vary from 26.8 degree Celsius to 29.6 degree Celsius, and the average value lies within the standard range

2) Measurement of Air Velocity

Air velocity is identified by measuring the air velocity in the rooms of the building by the means of digital thermometer. Digital thermometer shows the air velocity in m/s. Grids are plotted in the room, where the anemometer is placed at a suitable height, with the air source switched ON and the measurement is taken in the different grid points. The readings are observed and analysed, taking the measurements from each room at different time intervals.

The readings obtained from the anemometer in three different timings in different rooms were found to vary from 0.10 m/s to 0.7 m/s and the average value lies within the standard range.

3) Measurement of Sound Level

Sound level meters are used to measure the sound in a given point. The output unit is dB (decibel). Grids are plotted in the room, and the sound level meter is placed at a suitable height to obtain the sound readings, selecting the suitable decibel range in the sound level meter. The readings are observed and analysed, taking the measurements from each room at different time intervals.

The readings obtained from the sound level meter in three different timings in different rooms were found to vary from 53.00 dB to 60.00 dB and the average value lies within the standard range.

4) Measurement of Light Intensity

Lux meters are used to measure the light intensity at a given point. The output value obtained is lux in unit. Grids are plotted at suitable intervals in the room where which the lux meters are placed at suitable height, according to the height of the window. The readings are observed and analysed, taking the measurements from each room at different time intervals.

The readings obtained from the lux meter in three different timings in different rooms were found to vary from 19 lux to 34 lux and the average value lies within the standard range.

V. DISCUSSIONS AND CONCLUSION

A. *RELIABILITY OF QUESTIONNAIRE SURVEY*

The reliability or internal consistency of the questionnaire survey was analysed using Cronbach's Alpha. Likert scale rating scale was used for the analysis of the questionnaire survey. Likert scale is a five point scale which is used to allow the individual to express how much they agree or disagree with a particular statement. Likert scale (typically) provides five possible answers to a statement or question that allows respondents to indicate their positiveto-negative strength of agreement or strength of feeling regarding the question or statement.

TABLE 2 Five Point Likert Scale – Numerical Values

Answers	**Numerical Scale**
Very Dissatisfied	1
Dissatisfied	2
Neutral	3
Satisfied	4
Very Satisfied	5

The analysis was done using SPSS software support and the alpha value obtained was 0.927 which rates the reliability or internal consistency of the survey as "good". The rule of thumb (Table 2) was followed to determine the rating of internal consistency of the survey.

TABLE 3 Temperature Readings

	Living room				Dining Room				Kitchen				Master Bedroom			
11:00 AM	27.40	27.50	27.50	27.40	27.50	27.50	27.50	27.40	27.60	27.50	27.50	27.60	27.40	27.50	27.50	27.40
	27.50	27.40	27.50	27.40	27.60	27.40	27.40	27.40	27.60	27.40	27.50	27.60	27.40	27.40	27.50	27.40
	27.60	27.50	27.50	27.50	27.60	27.60	27.60	27.50	27.60	27.50	27.50	27.50	27.40	27.50	27.50	27.50
	27.60	27.50	27.60	27.50	27.60	27.60	27.60	27.60	27.60	27.50	27.60	27.50	27.60	27.50	27.60	27.50
2:00 PM	29.50	29.60	29.40	29.50	29.60	29.60	29.50	29.50	29.60	29.60	29.40	29.50	29.50	29.60	29.40	29.50
	29.50	29.60	29.50	29.50	29.60	29.40	29.40	29.50	29.50	29.60	29.50	29.50	29.50	29.60	29.50	29.50
	29.40	29.60	29.50	29.50	29.40	29.60	29.50	29.50	29.60	29.60	29.50	29.50	29.40	29.60	29.50	29.50
	29.40	29.60	29.60	29.40	29.40	29.50	29.60	29.40	29.40	29.60	29.60	27.00	29.40	29.60	29.60	29.40
4:00 PM	26.80	26.90	26.90	26.90	26.80	26.90	26.80	26.90	26.90	26.90	26.90	26.90	26.80	26.90	26.80	26.90
	26.90	26.80	26.90	26.80	26.90	26.80	26.90	26.80	26.90	26.80	26.90	26.80	26.90	26.80	26.90	26.80
	27.00	26.90	26.80	26.80	27.00	26.80	26.80	26.80	27.00	26.90	26.80	26.80	27.00	26.80	26.80	26.80
	27.00	26.90	26.80	26.90	27.00	26.90	26.80	26.90	27.00	26.90	26.80	26.90	27.00	26.80	26.80	26.80

TABLE 4 Air Velocity Readings

	Living room				Dining Room				Kitchen				Master Bedroom			
11:00 AM	0.30	0.40	0.20	0.20	0.40	0.40	0.20	0.20	0.30	0.30	0.20	0.20	0.30	0.30	0.20	0.20
	0.30	0.20	0.30	0.30	0.20	0.20	0.30	0.30	0.30	0.20	0.30	0.30	0.30	0.20	0.30	0.30
	0.20	0.30	0.30	0.10	0.20	0.30	0.30	0.10	0.20	0.30	0.30	0.10	0.20	0.30	0.30	0.10
	0.30	0.20	0.10	0.10	0.30	0.20	0.10	0.10	0.30	0.20	0.10	0.10	0.30	0.20	0.10	0.10
2:00 PM	0.40	0.50	0.50	0.60	0.40	0.50	0.50	0.60	0.40	0.50	0.50	0.60	0.50	0.50	0.50	0.40
	0.50	0.40	0.50	0.50	0.50	0.40	0.50	0.50	0.50	0.40	0.50	0.50	0.60	0.50	0.40	0.50
	0.50	0.60	0.70	0.40	0.50	0.60	0.70	0.40	0.50	0.60	0.70	0.40	0.50	0.60	0.70	0.40
	0.60	0.50	0.70	0.70	0.60	0.50	0.70	0.70	0.60	0.50	0.70	0.70	0.70	0.50	0.70	0.70
4:00 PM	0.30	0.40	0.20	0.20	0.40	0.40	0.20	0.20	0.30	0.30	0.20	0.20	0.30	0.30	0.20	0.20
	0.30	0.20	0.30	0.10	0.20	0.20	0.30	0.30	0.30	0.20	0.20	0.30	0.30	0.20	0.10	0.30
	0.20	0.10	0.30	0.30	0.20	0.10	0.30	0.10	0.20	0.20	0.30	0.10	0.20	0.30	0.30	0.10
	0.10	0.20	0.10	0.10	0.20	0.20	0.10	0.10	0.30	0.20	0.10	0.10	0.30	0.20	0.10	0.10

TABLE 5 Sound Intensity Readings

	Living room				Dining Room				Kitchen				Master Bedroom			
11:00 AM	55.00	53.00	54.00	55.00	55.00	53.00	54.00	55.00	55.00	56.00	54.00	55.00	55.00	53.00	53.00	55.00
	54.00	55.00	55.00	56.00	55.00	55.00	55.00	56.00	56.00	55.00	56.00	56.00	54.00	55.00	55.00	56.00
	56.00	54.00	56.00	54.00	56.00	56.00	56.00	54.00	56.00	56.00	56.00	54.00	56.00	54.00	56.00	54.00
	55.00	53.00	55.00	55.00	55.00	53.00	55.00	55.00	55.00	53.00	55.00	55.00	53.00	53.00	55.00	55.00
2:00 PM	56.00	55.00	56.00	55.00	56.00	56.00	56.00	55.00	57.00	56.00	58.00	55.00	58.00	55.00	56.00	55.00
	55.00	56.00	56.00	59.00	55.00	58.00	56.00	59.00	56.00	56.00	56.00	60.00	57.00	56.00	57.00	59.00
	56.00	57.00	58.00	56.00	56.00	57.00	58.00	56.00	58.00	57.00	58.00	56.00	56.00	57.00	58.00	56.00
	57.00	58.00	57.00	57.00	57.00	58.00	57.00	57.00	57.00	58.00	57.00	57.00	57.00	58.00	57.00	57.00
4:00 PM	54.00	55.00	54.00	55.00	54.00	55.00	54.00	55.00	54.00	55.00	54.00	55.00	54.00	55.00	54.00	55.00
	56.00	55.00	55.00	56.00	56.00	55.00	55.00	56.00	56.00	55.00	55.00	56.00	56.00	55.00	55.00	56.00
	56.00	54.00	56.00	54.00	56.00	54.00	56.00	54.00	56.00	54.00	56.00	54.00	56.00	54.00	56.00	54.00
	55.00	53.00	55.00	55.00	55.00	53.00	55.00	55.00	55.00	53.00	55.00	55.00	55.00	53.00	55.00	55.00

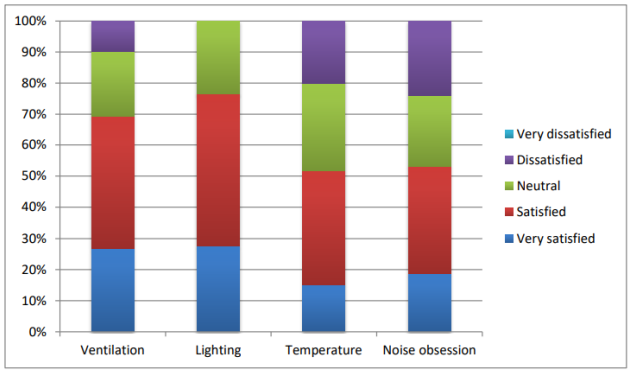
TABLE 6 Light Intensity Readings

	Living room				Dining Room				Kitchen				Master Bedroom			
11:00 AM	27.00	25.00	26.00	26.00	27.00	25.00	26.00	26.00	27.00	25.00	26.00	26.00	27.00	25.00	26.00	26.00
	25.00	25.00	25.00	27.00	25.00	25.00	25.00	27.00	25.00	25.00	25.00	27.00	25.00	25.00	25.00	27.00
	26.00	27.00	27.00	25.00	26.00	27.00	27.00	25.00	26.00	27.00	27.00	25.00	26.00	27.00	27.00	25.00
	27.00	26.00	26.00	25.00	27.00	26.00	26.00	25.00	27.00	26.00	26.00	25.00	27.00	26.00	26.00	25.00
2:00 PM	29.00	30.00	32.00	33.00	29.00	30.00	31.00	33.00	29.00	30.00	32.00	33.00	29.00	30.00	32.00	33.00
	32.00	32.00	30.00	33.00	32.00	32.00	30.00	33.00	32.00	32.00	30.00	31.00	32.00	32.00	30.00	32.00
	33.00	33.00	33.00	30.00	31.00	31.00	33.00	30.00	31.00	33.00	33.00	30.00	33.00	33.00	32.00	30.00
	33.00	34.00	32.00	32.00	33.00	34.00	32.00	32.00	33.00	34.00	30.00	32.00	32.00	34.00	32.00	32.00
4:00 PM	26.00	23.00	22.00	26.00	26.00	22.00	22.00	26.00	26.00	23.00	22.00	26.00	26.00	23.00	22.00	26.00
	22.00	22.00	25.00	27.00	22.00	22.00	25.00	27.00	22.00	22.00	25.00	27.00	22.00	22.00	25.00	25.00
	24.00	27.00	26.00	24.00	23.00	27.00	27.00	24.00	22.00	27.00	27.00	24.00	21.00	21.00	25.00	22.00
	23.00	22.00	26.00	25.00	23.00	22.00	26.00	25.00	23.00	22.00	26.00	25.00	21.00	22.00	19.00	22.00

B. OCCUPANT FEEDBACK AND RESPONSES

The graphical representation of the occupant responses and feedbacks on the questionnaire survey is as follows. The respondents were to answer 20 number of queries which is related to the performances of the building directly. Data collection was done on 103 persons, with the means of Google form and the responses are as follows

FIG 1 QUESTIONNAIRE RESPONSES



C. IEQ PARAMETERS

The IEQ Parameters – Thermal comfort, sound level, light intensity and air quality was measured using the means of digital thermometer, sound level meter, lux meter and anemometer respectively. The living room, dining room, kitchen and the master bedroom area was chosen for the study and analysis. The readings were observed on three different time intervals and an average of these in a room is specified.

FIG 2 Results of Instrument Observation

Average value of/in	Living Room	Dining Room	Kitchen	M. Bedroom	Standard
Temperature (Celsius)	27.96	27.96	27.93	27.94	23-26
Air velocity (m/s)	0.33	0.33	0.33	0.33	0.15 - 0.5
Sound intensity (dB)	55.35	55.48	55.69	55.40	50-70
Light intensity (lux)	27.42	27.29	27.27	26.81	30-500

The average temperature value obtained in different rooms of the building is 27.94 degree Celsius which is within the range. The air velocity value obtained on an average is 0.33 m/s which is within the standard range of 0.15 to 0.5 m/s. Sound and light intensity values were found to be 55.48 dB and 27.19 lux respectively which is also within the permissible standard range.

Clearly, the survey concludes there is a need of improvement in the building performances post occupancy and the responsible personals must be focusing more to these whilst the design phase of the building is in process.

D. REMEDIAL MEASURES

The average readings/values obtained from the observations made using the equipment's for temperature, air velocity, sound intensity and light intensity is within the specified standard range. As the readings are found within the comfortable standard range, additional requirement of remedial measures to improvise the parameters are not fully necessary. Nevertheless, as to enhance the performances further, artificial sources may be used. Use of air conditioners for a better thermal comfort, installing false ceiling for better acoustic performance, fixing of lights with adequate wattage for better light comfort are some of few examples.

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