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Post occupancy evaluation of IEQ parameters in residential buildings.

Evaluación posterior a la ocupación de los parámetros IEQ en edificios residenciales.

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ABSTRACT

The post-occupancy evaluation (POE) is a measure of a building's performance that can assist property owners and managers in understanding how effectively a facility is operating, how its performance stacks up against benchmarks or comparable buildings, and how a building may be enhanced. A thorough understanding of a building's operation enables one to directly correlate improvements to older or newer buildings as well as corrective actions with real performance. There is a tonne of material on POE in commercial structures, but less in the residential one. This small project seeks to quantify the IEQ characteristics in a residential building and gauge occupant satisfaction levels. On the basis of the sample sizes chosen, a thorough questionnaire survey is carried out for the research. The city of Kochi is the main destination under consideration because of its interesting geographical and climatic characteristics. The project's main goals are to determine the level of resident satisfaction, measure the IEQ factors in a residential building, and, if necessary, recommend solutions. The conclusions and outcomes are examined in light of several variables. The prioritizing of the building performance criteria will benefit from the findings.

Keywords: POE, IEQ, Performance, residential

RESUMEN

La evaluación posterior a la ocupación (POE) es una medida del desempeño de un edificio que puede ayudar a los propietarios y administradores de propiedades a comprender qué tan efectivamente está operando una instalación, cómo se compara su desempeño con los puntos de referencia o edificios comparables, y cómo se puede mejorar un edificio. Una comprensión profunda del funcionamiento de un edificio permite correlacionar directamente las mejoras en edificios más antiguos o nuevos, así como acciones correctivas con el desempeño real. Hay una tonelada de material en el POE en estructuras comerciales, pero menos en las residenciales. Este pequeño proyecto busca cuantificar las características IEQ en un edificio residencial y medir los niveles de satisfacción de los ocupantes. Sobre la base de los tamaños de muestra elegidos, se lleva a cabo una encuesta exhaustiva para la investigación. La ciudad de Kochi es el principal destino considerado debido a sus interesantes características geográficas y climáticas. Los principales objetivos del proyecto son determinar el nivel de satisfacción de los residentes, medir los factores IEQ en un edificio residencial y, si es necesario, recomendar soluciones. Las

conclusiones y resultados se examinan a la luz de varias variables. La priorización de los criterios de rendimiento del edificio se beneficiará de los resultados.

Palabras clave: POE, IEQ, Rendimiento, residencial

INTRODUCTION

An important factor in the construction process and the growth of client relationships is customer satisfaction. As construction companies deal with more competition, customer relations and happy customers are becoming more and more crucial. Construction companies can differentiate themselves from rivals and gain a sustainable competitive advantage by focusing on customer satisfaction. The main goal of a building is to provide its residents with a comfortable interior environment in which they may engage in a variety of activities, including work, study, leisure, family life, and social interactions. To do this, buildings are designed, planned, built, and managed in accordance with the standards and guidelines established by authorities, professionals, and experts who are thought to have sufficient knowledge of user requirements and expectations. A well-designed building is one that is structurally sound, aesthetically pleasing, and functional. It is a structure that uses few resources to provide more than was asked for. The necessity for architects and designers to address the end users of their commodities (buildings or other facilities) has not yet been completely acknowledged, in contrast to other industries where the customer experience is the major driving factor. The government, professionals, and experts who are supposed to have a thorough understanding of user needs and expectations established standards and specifications for buildings, but these standards and specifications do not adapt to changing user needs and expectations. Therefore, regular performance evaluations and research into and comprehension of user needs, expectations, and goals can aid in enhancing building performance. One of the best methods for getting performance data on existing structures is POE, or post-occupancy evaluation. A systematic study of a building's performance while it is in use, called a post-occupancy evaluation (POE), usually includes but is not limited to user perception analysis and serves a number of purposes. The post occupancy evaluation, or POE, is a performance evaluation of existing buildings that can assist property owners and managers in better understanding how effectively a facility is functioning, how its performance compares to benchmarks or similar structures, and how a building might be improved. A thorough comprehension of a building's operation can be utilized to correlate its real performance with either new or existing building innovations or corrective measures. Regarding the POE of commercial buildings, there is a wealth of knowledge available, but there aren't many comparable, consistent principles in the residential sector. In order to make sure that the building's performance meets the tenants' needs, post-occupancy evaluation, which is a component of building performance evaluation, must be conducted on a regular basis and as a requirement.

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POST OCCUPANCY EVALUATION (POE)

The act of evaluating buildings after they have been constructed and occupied for some time in a methodical and thorough manner is known as post occupancy evaluation. Post-occupancy evaluations are used to enhance how buildings are utilized to support wellbeing and productivity. It serves the following purposes in particular: 1) Account for building quality 2) Inform planning and briefing (programming) for new construction and renovations3) Address construction/use issues (such as change management and new work practices).Both quantitative and qualitative data may be incorporated into POE techniques. The majority of POEs will entail asking the inhabitants of the location being examined for comments; this could be accomplished using a variety of survey methodologies, such as a questionnaire, an interview, or a focus group. Environmental indicators including temperature, noise levels, lighting levels, and indoor air quality can be monitored in addition to occupant feedback to help improve a building's environment. POEs now frequently contain sustainable metrics including energy use, trash production, and water utilisation. Other regularly employed quantitative Space metrics such as occupational density, space utilisation, and tenant efficiency ratio are examples of measures. Cost, A significant statistic in building evaluation, either represented as the project cost per square meter or the total cost of occupancy, may be contrasted with tenant feedback to provide a better understanding of value. Once the building is occupied and in use, post occupancy evaluation (POE), which focuses on the facility's tenants and operational performance, is one of the BPE process's activities. It's critical to understand how well the building preserves the satisfaction and comfort of its users.BPE can use post-occupancy evaluation (POE) as a key component. In order to do this, feedback (soft data) from the building's residents would need to be gathered through surveys, interviews, and/or workshops, ideally at least a year after the building had been occupied to account for at least one seasonal cycle.

The aforementioned publications stressed the significance of occupant satisfaction in a variety of building types, including residential, non-residential, commercial, and industrial structures. The design of the structure, its elements, rooms, comfort, and indoor environmental quality indicators including thermal, visual, and other comfort levels are the key characteristics evaluated. Any building's performance for which the BPE tool was utilised must be thoroughly evaluated. The Post Occupancy Evaluation, or POE surveys, was determined to be the most useful instrument for evaluating performance after occupation. Most frequently, the mean of the POE survey was calculated using the questionnaire survey, which offers ratings ranging from extremely poor to very acceptable. The results of the analysis were most valuable to designers, builders, and architects since they let them assess the quality and utility of the items they produced or intended to deliver. When planning, constructing, and building pleasant homes, the need of considering pertinent information from end-users or residents of residential complexes is underlined. However, non-residential buildings were the subject of the majority of studies. Therefore, it is vital and inevitable that residential unit quality needs to be improved.

METHODOLOGY

Identification of performance attributes

A Post Occupancy Evaluation (POE) on the occupant satisfaction levels of residential buildings would be based on a number of factors. The user/occupant input would be the main source of data utilised to evaluate the functioning of any developed facility. The primary objectives of a facility provider are to meet the needs, demands, and aspirations of users. It is necessary to evaluate the built facility in terms of how well it satisfies user requests and expectations in order to obtain the appropriate input during the building performance review. An online questionnaire was employed to evaluate the post-occupancy review. These built facility characteristics are selected based on the literature review and were included in the questionnaire survey. These include the four IEQ parameters that were measured, ie, Thermal comfort, Acoustic comfort, Lighting quality, Indoor air quality.

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 to determine the satisfaction levels of the occupants of the residential buildings in Kochi. A questionnaire with 20 queries was 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

Selection of Sample

As the study focuses on the post occupancy evaluation of residential buildings 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.

TABLE 2 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

INDOOR ENVIRONMENTAL QUALITY (IEQ) PARAMETERS

The conditions inside the structure are most simply referred to as the Indoor Environmental Quality (IEQ). In addition to access to daylight and vistas, pleasant acoustics, and occupant control over lighting and thermal comfort are also included in good air quality. It may also involve the space's functionality, such as if the design makes it simple to reach people and tools when needed and whether there is enough room for occupants. Building managers and operators can improve occupant satisfaction by taking into account all IEQ factors rather than just concentrating on temperature or air quality. The thermal comfort, air quality, lighting quality, and acoustic comfort are considered the Indoor Environmental Quality (IEQ) factors. To offer an indication of how these parameters are performing across the building, these parameters are measured in the second phase using a sample taken from the structure's principal spaces. Mechanical tools like an anemometer, a lux metre, a digital thermometer, and a sound level metre are used to perform these tasks. When IEQ parameters are measured and values are produced that are better, the building performs better as planned.

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

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.

TABLE 3 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

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.

Table 4 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

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.

Table 5 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

RESULTS AND DISCUSSION

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 positive to-negative strength of agreement or strength of feeling regarding the question or statement.

Table 6 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.

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

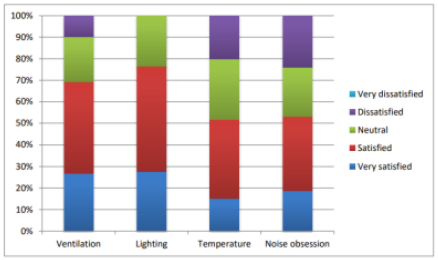

Fig 1 Questionnaire Responses

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.

Table 7 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.

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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