

Occupant satisfaction: a measure of Green Building Performance

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Abstract

Green building certification is standard practice for ensuring positive performing buildings during their construction and operational phase. Throughout the lifecycle of the building, the major consumption of resources occurs in the operational phase, when occupants interact with the building systems and spaces for their comfort and productivity. Building performance is largely a measure of the number of natural resources it consumes for its work and the quality of spaces it provides for its occupants. Occupant perception and satisfaction within an environment is an implicit parameter that has a huge impact on building performance. This parameter of performance is hardly attempted for comprehension or quantification by building operators, managers, and owners by conducting post-occupancy evaluation (POE) studies. This lacuna in building industry practice leads to a gap in anticipated building operational performance. Therefore, this paper is an attempt to highlight the significance of occupant satisfaction in achieving green building performance targets.

Keywords - Building operational energy Performance, Occupant Satisfaction, Post Occupancy Evaluation (POE).

1. Introduction

Buildings play a critical role in overall environmental sustainability. Throughout the building life cycle construction, occupancy, renovation, repurposing, and demolition, have a huge impact on land use, material use, waste generation, atmospheric emissions, water, and energy consumption (Gupta, Gregg, Manu, Vaidya, & Dixit, 2019). Other than these mentioned effects on the environment, buildings/spaces also have effects on their occupant's physical/mental health, productivity, and satisfaction. In response to these, Green Building certification systems provide building experts with a global standardized yard scale to measure a building's impact on the environment and occupants. At large, Green building certification systems are based on similar domains like site sustainability, energy efficiency, water efficiency, material use, indoor environmental quality (IEQ), and waste management (Honnekeri, Brager, Manu, & Rawal, 2014). Within these domains of green building certification systems, the environmental benefit is indisputably the prime benefit, but there are several unspoken benefits as well that are addressed to occupant well-being- comfort and satisfaction majorly under the IEQ section. The green buildings industry has a deeper impact on the social transformation of society. It is not only the building designers and owners but it propagates a larger role to its occupants like understanding of design philosophy, generation of green ideologies, and encouraging pro-environmental behaviors. The provision of awareness, education, and training to occupants, a minor feature within the green rating systems, helps to regulate their behavior in using systems and operating the buildings which later affects the building performance significantly (Elham, Song, Angela, & Ying, 2017).

Published literature highlights the fact that green building designs do not always operate ideally as anticipated (Al horr, et al., 2016). In such a scenario strategies adopted in a green building may not always facilitate occupant's desired comfort conditions, therefore, it is of great significance to ensure that energy-efficient systems, technologies, operations, and measures do not have an undesirable impact on occupants' health, productivity, comfort and perception of indoor space, which may incite undesired adaptive behaviors of occupants later leading to altered unpredicted building performance (Kim & Kim, 2020). In this context, it is important to investigate how occupants respond and interact with green building technologies and find measures to sustain high energy performance along with desired occupant satisfaction (Kim & Dear, 2012).

2. Impact of space environmental factors on Occupant Satisfaction

People spend almost 90% of their life in indoor environments (houses, schools, work environments, etc.) and the effects of indoor conditions on human health cannot be ignored (Fantozzi & Rocca, 2020). It is of prime importance for fulfilling a space's purpose and productivity that occupants are comfortable, healthy, and satisfied. It is imperative for occupants that their psychological comfort and assurance at work are fulfilled through quality designs and efficient operation of space (Asmara, Chokor, & Srour, 2014). Satisfaction or dissatisfaction within a working/living environment space can be a subjective perceived opinion of an occupant which is also influenced by personal and contextual characteristics (Abbaszadeh, Zagreus, Lehrer, & Huizenga, 2006).

Building occupants are exposed to numerous indoor environmental factors like thermal, visual, acoustic, and air quality factors (Schweiker, et al., 2020). Various research indicates that there exists a very complex relationship between space environmental factors and occupant perception of satisfaction (Delzende & Song, 2017). The overall interactive outcome of this determines occupants' indoor environmental perception, and satisfaction leading to adaptive behavior toward its environmental space factors. These factors can have both short and long-term impacts on the occupants (Al Horr, et al., 2016). Out of all environmental space factors, IEQ factors determining occupants' comfort levels are of high significance. The building owners claim that the cost of the occupant to do the job is substantially higher than the cost of energy, which goes contradictory if workplace designers fail to provide workers with an environment healthy, comfortable, and productive through improved space environmental parameters (Asmara, Chokor, & Srour, 2014).

3. Studies on Occupant Perception and Satisfaction

Conducting a POE study and surveying occupants, to understand occupant interaction patterns and evaluate satisfaction levels within a space is the most used method throughout. There exists a varied range of published studies conducted in other countries, but hardly any on Indian green buildings (Gupta, Gregg, Manu, Vaidya, & Dixit, 2019). Most POE studies aiming to investigate occupant satisfaction in the context of IEQ factors of space have investigated specific aspects such as thermal comfort, visual comfort, ventilation, stuffiness, and sound privacy. Some studies indicate that along with IEQ factors other space elements such as exposure to nature and daylight, noise, and ergonomics as well as opportunities for social gathering, relaxation, and exercise also impact occupant satisfaction (Kamaruzzamana, Egbu, Zawawi, Ali, & Che-Ani, 2011).

Interdisciplinary studies on human perception, behavior, and building performance evaluation have highlighted a wide range of facts, emphasizing the influencing factors and their implications on occupant satisfaction scores (Frontczak, et al., 2012). The satisfaction levels of occupants to a very great extent are influenced by the perception or image they have of their working/ living space/ environment. In comparison to green versus conventional buildings, it is found that occupants are more appreciative of their environment, even in cases of discomfort (Berquista, M. Oufb, & O'Brien, 2019). The Image of enhanced performance i.e., the green building certification label, has a positive impact on the user's perception, studies have revealed that the occupant satisfaction score with their workspace is much higher for a green building compared to a conventional building (Max Paul & Dear, 2010).

It is also found that the occupant's awareness of its building performance and system efficiency influences his perception of space psychologically. Even in the cases where all IEQ parameters of spaces are equally performing, a green certification label on a building can have a positive impact, influencing occupant perception and leading to scoring higher on occupant satisfaction compared to a non-green building (Holmgren, Kabanshi, & Sorqvist, 2017). This positive image influencing occupant perception was also investigated in a study (Khoshbakht, Gou, Dupre, & Best, 2018), highlighting that occupants of a green building even if they are experiencing discomfort in certain IEQ parameter, tends to forgive the discomforting conditions due to the overall positive image of the building performance. However, an experimental study (Geng, Ji, & Zhu, 2017) conducted to find the relationship between various IEQ factors and their related impact on occupant perception highlights that in some scenarios the unsatisfactory performance in any one of the factors not only affected the associated comfort levels of that factor but also had a comparative and relative impact

on the perception of other IEQ factors indirectly leading to lower satisfaction scores. This study also highlighted the fact that the occupant's expectations from the environment in terms of comfort and satisfaction is higher in better-performing spaces or green-labeled buildings.

An analytical study to investigate the impact of interior design space layout on occupant energy behavior where space was studied by dividing into destination, circulation, and energy consumption spots highlights the significance of space design and how it influences the choices of activities and potential behavior (Delzende & Song, 2017). A detailed literature review of the relation between IEQ and occupant satisfaction is published where experts imply that top-rated green buildings with high IEQ scores, that have implemented measures to achieve improved IEQ conditions within the spaces have a positive influence on the satisfaction and perceived productivity of occupants (Kim & Kim, 2020).

In contradiction with the above facts, in a study where 65 LEED-certified and 79 conventional buildings were surveyed in the US, to investigate the performance and occupant satisfaction levels, the outcomes revealed that green buildings and conventional buildings have equivalent occupant satisfaction scores with the IEQ factors, building, interior, and workspace design, highlighting the fact that there is no substantial influence of LEED certification on occupant satisfaction (Altomonte & Schiavon, Occupant satisfaction in LEED and non-LEED certified buildings, 2013). A similar study was conducted to investigate occupant satisfaction in UK BREEAM- certified office buildings and showed similar results that certification does not have a substantial effect on occupant satisfaction (Altomonte, Saadouni, & Schiavon, Occupant Satisfaction in LEED and BREEAM-Certified Office Buildings, 2016). The above studies highlight the fact that any building or space, that maintains a positive optimal balance with its efficient operations, human-centric space designs, and ethical working social norms, like encouraging positive/constructive interactions and reducing negative/relegating distractions, could help in maintaining desirable effects on occupant's satisfaction and perceived productivity (Gocer, Candido, Thomas, & Göçer, 2019).

The results from the POE study on 77 Australian open-plan offices emphasize a strong link of space physical configuration /space design with occupants' perceived productivity and satisfaction levels. Evaluating several features of a building design and operations like aesthetic quality of space and building, comfort conditions from environmental parameters- visual, thermal, IEQ and acoustics, personal controls, outside views and connections to spaces, privacy, security, maintenance, and individual space configuration. This study highlights the same fact that a good space physical configuration /space design with maintained building operations, positive occupant working conditions/experience, and regular working hours have a high association with the overall image of a workspace building for users (Gocer, Candido, Thomas, & Göçer, 2019). However, it is difficult to directly determine what environmental factors of space have a major role in inducing satisfaction or dissatisfaction to a user.

4. Parameters affecting occupants' satisfaction

The Reviewed literature supports that the overall space can affect its users through its performance or its experience/ perception. A study to measure user satisfaction broadly classifies a method within two main clusters such as performance-based building user satisfaction measurements and perception-based building user satisfaction measurements (Shafaghat, et al., 2016).

- **Performance-based IEQ parameters**

Thermal comfort – Temperature & humidity Levels, Visual Comfort- daylight & artificial light levels, Acoustic comfort – Noise control, Indoor Air Quality, Odour, CO₂ levels, pollutants, Ventilation & Air Exchange rate.

- **Perception-based -Space design parameters**

Aesthetics value, outside visual connections, Furniture, and Partition layouts, Colour and Material, Privacy, Cleanliness/Maintenance, and Building/Space System Controls.

The satisfaction of building occupants is affected by the above all parameters of space. Space constitutes tangible and intangible factors that form a relationship with the occupant. The Performance

based IEQ parameters are quantifiable and can be measured space-wise, whereas the Perception based – space design parameters are subjective and qualitative. These parameters need to be collected for each user of the space and results may differ for each enquiry.

To understand the overall process and linkages it is necessary to evaluate all the above-mentioned parameters of a space that interacts with the occupant and helps to develop perceived satisfaction. These Space environmental parameters should form the core of all inquiries aiming toward occupant satisfaction.

5. The relation between occupant satisfaction, adaptive behavior & Building Performance

The assessment of occupants' perceptions and satisfaction within a building can provide valuable information about building performance (Kamaruzzamana, Egbu, Zawawi, Ali, & Che-Ani, 2011). It is a fact that the performance of occupants should be aligned with the building's performance to achieve the desired results of sustainability. There should exist a fine balance between energy and resource efficiency in a green building to provide a satisfactory and productive space for the occupants. For this, it is imperative to understand the engagement of occupants in the buildings. Occupant interaction and adaptive behavior within the building are strongly influenced by occupant satisfaction and perception which influences the building operations involving energy use and cost of operations thus forming a closed-loop (LBNL & Tsinghua University, November 2017). Technology and occupant adaptive behavior together hold the potential to achieve high-performing buildings and spaces. Space operational cost and energy consumed are greatly affected when occupants perform various actions to satisfy their physical, environmental, psychological, or physiological to achieve suitable indoor comfort conditions like adjusting thermostat settings to be warmer or cooler, opening windows for ventilation, turning on lights, pull down the window blinds and move around, among many other actions that significantly affect building operations (Belafi, Hong, & Reith, 2018).

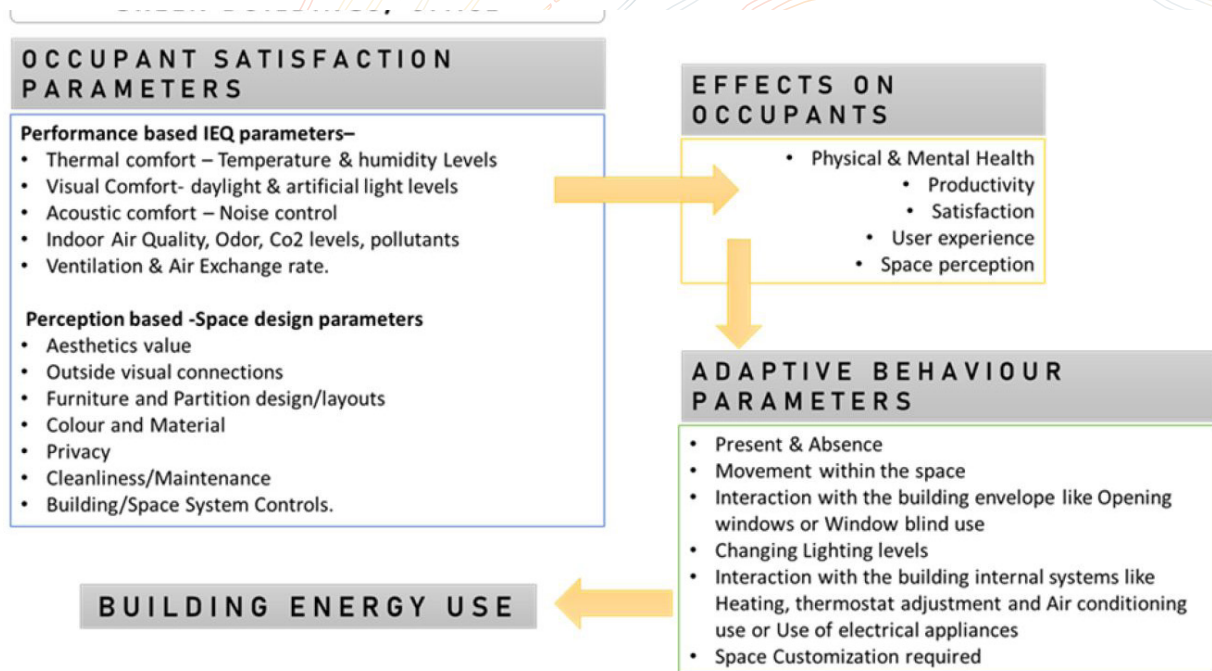


Figure 1: Illustrates the association between occupant satisfaction, adaptive behavior, and building performance

Experts claim that Occupant Adaptive behavior is the measure of user satisfaction and has the potential to improve building/space energy performance (Shafaghat, et al., 2016). However, Green building certification systems have not yet recognized a clear association between user satisfaction with adaptive behavior and energy efficiency. Within a green building code, the potential to enhance Indoor environmental quality (IEQ) is substantial. It is implied that a higher-ranked green building is high performing as well, with high-performance occupant comfort and comfort-related behavior

is high performing as well, with high-performance occupant comfort and comfort-related behavior aligned (Brown & Cole, 2009). A study conducted with this theory (Keyvanfar, Shafaghat, Majid, Lamit, & Ali, 2014) provides evidence that the occupant's adaptive behavior formed due to discomfort or dissatisfaction, contributes highly to operations energy use, this implies building occupants when not satisfied with the building operational features or systems and they may adapt the building indoor environment design according to their satisfaction level with individual interventions, which causes higher energy consumption.

A review paper (Sujanova, Rychtarikova, Mayor, & Hyder, 2019) published based on an analysis of more than 300 scientific publications between 1960 and 2019, covering topics concerning IEQ, energy efficiency, occupant comfort, health, sustainability, and adaptability of the built environment, highlights the necessity of a human-centric design of the built environment, where the efficiency of technology can be measured only if it is successfully implemented and used by the building occupants.

6. Data Collection and Quantification Methods

All over the globe, experts are attempting to arrive at an accurate methodology to integrate occupant satisfaction and behavior modeling into pre-and post-construction building energy efficiency approaches. Methods like surveying, surveillance, and simulations have been used by experts in various studies to evaluate the same (Grover & Brar, 2019). For POE investigations Occupant Survey-electronic or handouts with walkthroughs, interviews, and field measurements are widely used.

• Survey-based approach

To evaluate occupants' perception and satisfaction levels, longitudinal surveys are the most used method due to their relatively low cost of implementation and ease of communication (Berquista, M. Oufb, & O'Brien, 2019). A literature review published by (Li, Froese, & Brager, 2018) shows that the occupant long-term survey helps quantify subjective opinions through a series of questions with scaled answers or responses and then benchmarks the outcomes. These types of longitudinal surveys are suitable for consistent building occupants who are exposed to the same space's conditions daily, over the long term (Berquista, M. Oufb, & O'Brien, 2019).

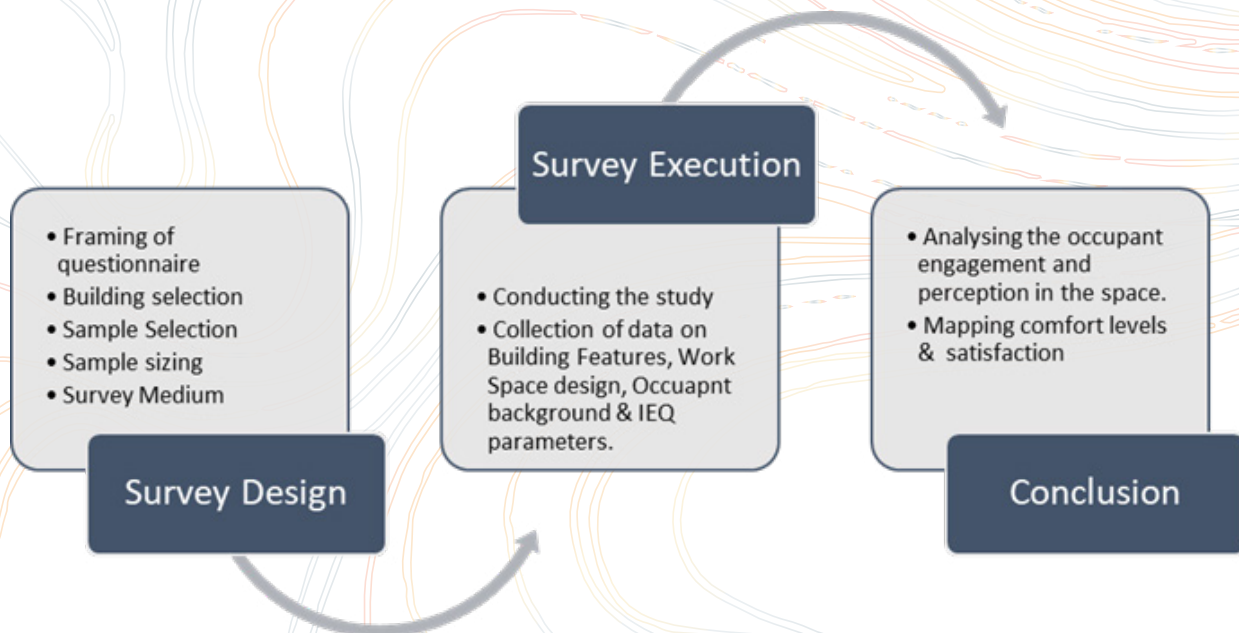


Figure 2: Illustrates the process of conducting a survey

UC Berkeley published a literature review on established survey methodologies and identified 10 surveys that evaluate occupant comfort, perception, and satisfaction on space IEQ parameters (Clara & Stefano, 2011). Seven of the ten surveys were used for specific research projects and fell into disuse. This review highlights that the two most extensively used survey methods for long-term assessments are the Center for the Built Environment (CBE) survey and the Building Use Studies Occupant Survey (BUS). Another Survey tool recently developed and widely in practice is BOSSA-The Building Occupants Survey System Australia. It is an Australian-developed POE instrument for office buildings (Candido, Dear, Thomas, Kim, & Parkinson, 2012). All these survey methods are based on a similar base ground of assessing the results from occupants and their engagement with the built environment. Although they differ in their approach, features, and structure of the questionnaire. All three survey methods are closed-ended with multiple-choice answers and require participants to choose each possible answer independent of the others, on the continuum of responses, provided by the Likert scale. They all have been established, verified, and kept consistent over many years thus enabling reliable benchmarking. The BUS questionnaire has been developed in the UK and used worldwide, the CBE questionnaire is developed and implemented in the USA, whereas BOSSA has most of its implementation in Australia.

The mentioned established survey methods are well designed to investigate occupant satisfaction scores, primarily dealing with IEQ factors and space design. They are widely implemented in various other countries but when tested for application in Indian office buildings, the questions and structure need modifications as per the climatic context, regional context, working pattern, and social norms followed in the Indian workspace. Also, the structure of these survey methods does not focus largely on adaptive behavior linked with discomfort experienced in the specific environmental or non-environmental space parameter. These lacunas accentuate the need for developing an advanced method tool structure specific to the Indian workspace context (Grover & Brar, 2022). To address these issues for Indian workplace post-occupancy evaluation of occupant satisfaction and energy adaptive behavior, an advanced survey framework - Workplace Survey on Occupant Perception, Satisfaction, and Adaptive Behavior (WSOPSAB) is developed and in the testing phase. The design of WSOPSAB aims to evaluate this complete loop of interaction system of occupants within the building space (Grover & Brar, 2022).

7. Discussion

The consumption of resources like energy, water, and daylight, are the prime focused parameters of efficiency in green buildings but there exists a strong relationship between occupant perception, satisfaction levels, adaptive behavior, and building performance levels, which is still overlooked in current green building practice. The occupant-centric discussion presented in the paper with the building systems and the space environment has large implications on building performance that need to be acknowledged by all stakeholders of the building industry and considered throughout the building life cycle.

The foreign existing established quantification-survey methods highlighted in the paper are well verified to comprehend the occupant perception and satisfaction levels of the space but this is still open-looped as this method does not close the connection of occupant dissatisfaction to the mapping of occupant adaptive behaviors and then methodically leading its connection to the building overall performance. To address this gap WSOPSAB is an advanced tool or method that can investigate the complete link between satisfaction, and adaptive behavior of occupants that can be adopted as a solution to test the performance of Indian workspace buildings.

In the current practice of green buildings, professionals have yet not acknowledged that occupant satisfaction can be a measure to test the building performance but it holds large potential for improving efficiency levels leading to the overall sustainability and mitigating adverse effects of building sectors on planetary problems like climate change.

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