E-ISSN: 1116 - 2759 P-ISSN: 3027-0111
MPRI-EDIR | INTERNATIONAL JOURNAL OF EARTH DESIGN AND INNOVATION RESEARCH
VOL. 09 NO. 4 – JULY, 2025

ASSESSMENT AND OPTIMIZATION OF BUILDING PERFORMANCE (A CASE STUDY OF SOME SELECTED BUILDINGS IN KADUNA NORTH)

YUSUF MUHAMMAD WAZIRI
Department of Building, College of Environmental Studies, Kaduna Polytechnic

DOI: https://doi.org/10.70382/mejedir.v9i4.053

Abstract

The quest for sustainable and efficient building environments has intensified in response to escalating global concerns over energy consumption, environmental degradation, and rising costs of living. This study critically assesses and explores strategies for optimizing the performance of residential buildings in Kaduna North, Nigeria, with the overarching goal of enhancing energy efficiency, indoor environmental quality (IEQ), occupant comfort, and water utilization. Employing a multidisciplinary approach, the research integrates quantitative and qualitative performance metrics to examine selected buildings' operational characteristics. The methodology incorporates detailed performance evaluation across five major domains: energy usage, water efficiency, IEQ (including thermal comfort, indoor air quality, lighting, and acoustics), and post-occupancy satisfaction. By deploying surveys, on-site measurements, and comparative benchmarking, the study quantifies inefficiencies in current building practices, identifies critical performance gaps, and outlines practical optimization pathways. The findings reveal that while many buildings meet basic occupancy standards, they fall short in energy conservation, water use optimization, and environmental adaptability—factors that significantly impact both economic sustainability and user wellbeing. Key drivers such as the removal of government subsidies, increasing utility tariffs, and the broader socioeconomic pressures in Nigeria underscore the urgency of rethinking residential building strategies. The study

Keywords: Building Performance, Energy Efficiency, Indoor Environmental Quality (IEQ), Post-Occupancy Evaluation (POE), Water Efficiency.

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

also underscores the role of Post-Occupancy Evaluation (POE) in aligning building design with user needs, promoting energy-saving technologies, and guiding stakeholders—designers, developers, policymakers—toward data-driven decision-making for future developments. The implications of this research are twofold. Practically, it offers actionable recommendations for retrofitting existing structures and integrating sustainable practices into new designs. Theoretically, it advances the discourse on building performance in Sub-Saharan Africa, providing a replicable framework for similar assessments across urbanizing contexts. In conclusion, optimizing building performance is not merely a technical pursuit but a socio-economic necessity for achieving resilience, reducing carbon footprints, and enhancing quality of life in emerging urban centers.

Introduction

Background to the Study

The drive towards a sustainable built environment raises challenges for practitioners. These stem from the need to reduce energy consumption, integrate clean energy supplies and mitigate environmental impacts, all while meeting expectations for human wellbeing and economic growth (J.A. Clarke, J.L.M. Hensen, 2015).

Building performance is a term often used in the Architecture, Engineering and Construction (AEC) sector, typically in association with issues like the energy efficiency of buildings, indoor environmental quality, thermal comfort or lighting. Performance in general is an important concept in today's society which is strongly focussed on efficiency and quality (Pieter de Wilde, 2019).

With the significant increase in greenhouse gas emissions during the 21st century, and extreme weather events, addressing climate change has become a crucial concern in the coming decades. Global warming, in particular, has garnered significant attention (Kostantinos Gobakis, Dionysia Kolokotsa, 2017).

The construction industry has an important role to play in reducing the global warming. According to the International Energy Agency (IEA), global building-related carbon emissions amount to 10 billion t in 2019, accounting for 28 % of global carbon emissions. Among the various sectors that emit greenhouse gases (buildings, transport, industry and commerce), the total amount and share of carbon emissions from the building sector continues to grow (Siyue Guo, Da Yan, Shan Hu, Yang Zhang, 2021).

The imperative for improved efficiency and sustainability has made the optimization of buildings a crucial activity. Stakeholders include regulators, investors, and tenants who expect environmental responsibility and efficiency from building facilities.

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Optimizing building efficiency and performance is crucial to meeting global sustainability requirements. Building optimization is the methodical process of improving a building's operational efficiency. It focuses on reducing energy consumption, enhancing comfort levels, and minimizing environmental footprint.

Reducing greenhouse gas emissions is a primary goal of building optimization. This involves using renewable energy sources, like solar and wind power, and using green building materials with lower embodied carbon. Ultimately, sustainability in the building industry is about more than just consuming less energy; it's about designing structures that live in harmony with the environment.

Statement of the Problem

The removal of subsidy has directly contributed to the spiraling inflation, which has hit the prices of foodstuff, transportation, and essential services the hardest. This has created a burden on the average Nigerian, as their meager income is further stretched, making it increasingly difficult to afford necessities (This Day, 9th June, 2024). Hence, the need for assessment of building performance in order to come up with ways in which performance of building could be optimized so as to mitigate the rising cost of living seen in electricity tariffs, lack of pipe borne water among others.

Aim and Objectives

The aim of this research is to assess the performance of buildings within the Kaduna metropolis for improved efficiency and sustainability. This study has the following objectives:

1. To asses energy consumption patterns in the buildings.
2. To measure the indoor air quality, thermal comfort, lighting quality and acoustic performance of the buildings.
3. To evaluate water consumption in the buildings.
4. To evaluate occupants' comfort and satisfaction with use of the buildings.
5. To provide means of improving the performance of the building for efficiency and sustainability.

Research questions

1. What is the energy consumption patterns in the buildings i.e., HVAC systems, insulation, and lighting?
2. What is the building's Indoor Environmental Quality (IEQ) i.e., air quality, thermal comfort, lighting quality, and acoustics?
3. How efficient is the usage of water in the buildings?

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

4. Are the occupants comfortable and satisfied with the performance of the buildings?

Justification

The investigation will enhance design practice and guarantee the ongoing improvement of design methodologies. Property managers, building operators, and building occupants can all benefit from the Building Performance Assessment with comprehensive measurements and occupant feedback, which identify building features that are performing at their best and those that could be improved.

Scope and limitation

The scope of this investigation is the residential buildings within the Kaduna Metropolis.

LITERATURE REVIEW

The primary objective of a building is the provision of shelter, comfort, and safety for its occupants. Therefore, to attain this purpose buildings are designed, planned, constructed and managed according to certain codes and regulations, governed by experts and government bodies (N. Khalil, H.N. Husin, 2009). The adverse effect of climatic change and the increase in public environmental awareness in the building industry has resulted in the development of creative solutions to reduce the Green House Gas (D. Erten, K. Henderson, B. Kobas, 2009).

The operational performance of buildings (e.g., energy bills and comfort conditions) is influenced by a multitude of dynamic factors, including occupant behaviour, future climate and economic factors (D. Yan, W. O'Brien, T. Hong, X. Feng, H. Burak Gunay, F. Tahmasebi, A. Mah-davi, 2015).

Buildings consume more than 70% of the electricity and a large part of materials, water, and generate 60% of non-industrial waste (National Institute of Building Sciences, 2010). Embracing multiple aspects that surround a building such as site conditions, energy consumption, water efficiency, indoor environmental quality, material uses, innovation in design and regional characteristics, building optimization is "an integrative effort to transform the way built environments are designed, constructed, and operated" (Suk-Kyung Kim, Ying Hwang, Young S. Lee, William Corser, 2015). In optimized buildings, the consumption of energy, water, and other resources are greatly reduced by adopting various methods and energy and water saving technologies. Furthermore, building optimization aim to achieve high performance in human and environmental health via improved occupant productivity and comfort by providing better indoor environmental quality (USGBC, 2014).

Energy Performance

The three-world primary economic sectors of energy use are industry, transportation, and buildings. Buildings have a substantial share of the energy consumption all over the world which deserves to be looked at carefully for the efficient operation of such facilities. Many possible approaches are expected to appear to meet future energy developments related to each of these sectors of energy use. Changes in energy resources and prices are associated with changes in productivity growth. This will lead people not only to use less energy, but also to produce new systems that consume less energy (Mohammad Saad Al-Homoud, 2001).

Building energy performance assessment is crucial to ascertain the efficiency of energy use in buildings and is the basis to make any decision for enhancing energy efficiency. In order to assess the energy performance of existing buildings quantitatively, the energy use of the assessed buildings should be quantified first. The quantified energy use will be then used to compare with the assessment criteria to determine the energy performance quantitatively (Luis Pérez-Lombard, José Ortiz, Rocío González, Ismael R. Maestre, 2009). The building sector is the largest energy consumer exceeding industry and transportation sectors. Currently, the global energy use contributed by buildings is about 40% (Bart Poel, Gerelle van Cruchten, Constantinos A. Balaras, 2007), of which a significant proportion might be wasted due to various faults in building design, construction and particularly in operation stages (Luis Pérez-Lombard, José Ortiz, Rocío González, Ismael R. Maestre, 2009). Eliminating building energy problems and enhancing building energy efficiency is a promising approach to relieve the increasingly aggravated energy problems (Luis Pérez-Lombard *et al.*, 2009).

Building energy performance assessment is crucial to ascertain the efficiency of energy use and is the basis to make any decision for enhancing energy efficiency. It can provide building owners and/or tenants with understandable information regarding how much energy being consumed and how the performance being appraised comparing with benchmarks, which consequently should be a motivation for the building owners to improve the energy performance when the performance is deficient and certain cost-effective energy saving opportunities be identified. This initiative provides benefits of reducing operations and maintenance costs from the reduction of energy consumption. It also facilitates the CO_2 emission from the building sector (Luis Pérez-Lombard *et al.*, 2009).

When the energy saving and energy efficiency issues are concerned, essential questions confronted by most professionals and researchers are how to define and how to assess the energy performance of buildings? The term of energy efficiency is defined as "using less energy without compromising the performance of the building (Mohammad Saad Al-

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Homoud, 2001), and which can be achieved by reducing unnecessary energy use in buildings (Shengwei Wang, Chengchu Yan, Fu Xiao, 2012).

In the building sector, efforts toward designing and operating energy efficient buildings will continue. One measure of energy conservation may be in the shift in resource allocation, such as reducing the space air-conditioning load by the designing and using of climate-responsive buildings and materials, or constructing compact and tight building envelopes. This will be associated with the development and use of energy-efficient equipment (Mohammad Saad Al-Homoud, 2001).

Technological advances in building structural systems and materials, heating, air-conditioning, lighting and other human comfort-designed systems, as well as human needs and requirements for new spatial arrangements, new building types and the associated costs all lead to the necessary integration of building technology and aesthetics with the function of buildings. The increasing costs of energy and the environmental impact of the various sources of energy make optimum energy use a major objective in the design and operation of contemporary buildings. Therefore, performing the necessary energy analysis can help designers reach guided solutions in building design/operation decisions. Various building energy-analysis methods are available, ranging from simplified manual methods to detailed hourly computerized programs (Mohammad Saad Al-Homoud, 2001). The question is how much energy should be considered as the minimal energy input in order to provide the required services to a building? In other words, how to assess the building performance referring to energy aspect and judge whether any unnecessary energy use occurs in a building is an essential question to be answered. However, there is no unanimous agreement on this fundamental question so far (Shengwei Wang, Chengchu Yan, Fu Xiao, 2012).

Water Efficiency

Water stress is a global problem with far-reaching economic and social implications. At its roots lies a very basic supply-demand mismatch. While the demand for water is rising in all sectors, the quantity of good quality water that can be accessed with ease and low cost is declining (Murat Mirata, Tareq Emtairah, 2014).

The Concept of Water Efficiency

Water efficiency is an indicator of the relationship between the amount of water required for a particular purpose and the amount of water used or delivered (AQUASTAT, 2008). A related concept is water conservation where the emphasis is on the accomplishment of a function, task, process, or result with the minimal amount of water. While the two concepts are often used interchangeably, there is a difference between water

conservation and water efficiency. Water efficiency concerns reducing waste rather than restricting use. It also emphasizes the influence users can have on water consumption by making small behavioural changes to reduce water wastage and by choosing more water efficient process steps and products. Examples of water efficiency actions include fixing leaking taps, taking showers rather than baths, installing displacement devices inside toilet cisterns, and using dishwashers and washing machines with full loads (Murat Mirata, Tareq Emtairah, 2014).

Another important dimension to water efficiency is the emphasis on closing the water cycle through recycle and reuse. For example, water discharged from one activity can be reused for the same or a similar activity. In other cases, water may not be fit to be reused in the same activity but it can be reused for another one that can tolerate lower quality water, after applying some treatment if necessary. In such cases, reuse and recycling improve water efficiency at a system level. Collectively, all these steps fall under the definition of water efficiency, as their purpose is to obtain the desired result or level of service with the least necessary water (Murat Mirata, Tareq Emtairah, 2014).

Factors Motivating the Market for Water Efficiency

Today, there are a number of developments and trends that are affecting the landscape of water use and increasingly enabling markets for water efficiency products and services. Prominent examples include the following (Murat Mirata, Tareq Emtairah, 2014):

1. Energy Intensity of Water Is Increasing; As the quantity of clean and easily accessible water decreases, water needs to be increasingly located from sources that have high concentrations of impurities - such as oceans, brackish groundwater, or wastewater - and thus needs to be treated more extensively. In parallel, when sources closer to the point of use get reduced, water - a heavy material itself - needs to be pumped over longer distances. Water purification and transportation require considerable amounts of energy and therefore not only add to the cost of water but can also put pressure on the energy supply network.
2. Higher Value-Adding Uses Are Prioritized; As the demand for a limited resource i
3. ncrease, a natural tendency to allocate more of the resource to high value-adding activity prevails. This usually means prioritizing industrial and commercial use over agricultural use.
4. Water Risks for Businesses; For businesses and in particular those having a high level of direct or indirect water dependence, water-related risks and responsibilities are increasingly acknowledged by key stakeholders. Investors and creditors in particular are placing increasing demands on businesses to assess and communicate water-related risks as well as to develop strategies to address them.

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Businesses are also under growing pressure to adopt corporate responsibility measures that positively affect the quality and availability of water.

5. Awareness Of Individual and National Water-Footprint Is Increasing; Due to the expansion of global trade, environmental impacts and resource intensities of goods and services produced elsewhere are usually hidden from their consumers. Despite their error margins, the distressing information provided by initiatives like VirtualWater5 is raising consumer awareness about the water intensity of lifestyles. Such initiatives are intended to attract preference for goods that are less water-intensive.
6. Private Sector Participation; Water provision, and sanitation, has traditionally been a public responsibility. Publicly-managed water services, however, frequently suffer from technical and economic inefficiencies. Private players, who have a proven track record of running systems more efficiently, are thus increasingly brought into the water domain. This practice is prone to ethical questioning. As long as they remain transparent and accountable to water users, however, private actors appear to make a contribution.

Occupant Comfort and Satisfaction

According to (Behlou, 1991), post occupancy evaluation (POE) is a systematic evaluation of completed and occupied settings. It has its origins in academically based studies in the 1960s and the 1970s when evaluators were curious about how 'users' behaved in and reacted to buildings and was part of a larger effort to define the design process in terms of rational models derived from information gained through research. Post occupancy evaluation is "an examination of the effectiveness for human users of occupied designed environments" (Zimring, C.H., Reizenstein J.E., 1980). It is the process of evaluating buildings in a systematic manner after they have been occupied for some time (Preiser, W.F.E., Rabinowitz, H.Z., White E.T., 1988). The POE approach uses the occupants' needs as the criteria by which the building is judged, bases its conclusions on user impressions, and employs survey and interview methods (Behlou, 1991).

According to (Woon, N.B., Mohammad, I.S., Baba, M. & Nazri, N.Z.A., 2015), POE of building performance is vitally needed to ensure that building performance of government and public buildings and facilities is sustained (Nawawi, A.H., Khalil, N. 2008).

Conceptual Overview of Post Occupancy Evaluation

POE is a general term for a broad range of activities aimed at understanding how buildings perform once they are built, and how satisfied building users are with the environment that was created (Hewitt, D., Higgins, Heatherly and Turner, 2005). POE is a systematic

collection and evaluation of information about the performance of the building in use. By conducting POE, individual can measure the energy consumption of a building, and will also try to establish the level of comfort and satisfaction of the occupants of the residential building. By taking these factors into account, it will enable research to identify and improve the design, performance and fitness of the building in accordance with its purpose (Chikezie, C.E., 2014). POE is the evaluation of the performance of a building after it has been occupied (Nawawi *et al.*, 2002).

Building performance evaluation needs to take place at every stage of the building's lifecycle for maximum effectiveness. The term "POE" is used in this guidance as a catch-all to refer to both a review of the technical and functional performance of the building during occupation and a review of the project delivery process (Chikezie, C.E., 2014).

POE was established due to problems arising from the building industry, more especially in the care facilities such as mental hospitals, nursing homes, and correctional services (Riley, M., Kokkarinen, N., Pitt, M., 2010). POE is the process whereby a building has to be evaluated accurately once it has been built and occupied for some time (Carthey, 2006). POE is a general term for a broad range of activities aimed at understanding how buildings perform once they are built, and the level of satisfaction of building users with the environment thus created (Hewitt *et al.*, 2005). POE was derived from the 'occupancy permit', a document that is issued once the building has been inspected and is declared free from all defects and ready for occupation (Riley *et al*., 2010, as cited by (Emuze, F., Mashili, H., Botha, B., 2013).

The idea of POE was established in relations to the problems arising from the building industry, more especially in the care facilities such as mental hospital, nursing homes, school residence and correctional services (Riley *et al.,* 2010). The rapid housing development in the Second World War has led to the adoption n of POE in the built environment (Chikezie, C.E., 2014). Due to the urban renewal projects many houses which were built in Northern America, has forced the designers to accommodate the need of the lifestyle of the occupants (Riley *et al.,* 2010).

According to (Chikezie, C.E., 2014), office buildings are a key resource for all type of organizations including student housing, both public and private. There is a common understanding of an office in the residence which is a workplace that accommodates the information and knowledge processing activities of an organization including filing, planning and designing, supervising analysing deciding and communicating (Chikezie, C.E., 2014). Office buildings develop from the need to plan, coordinate and administer these activities (Pinder, J. Price, I., Wilkinson, S.J. & Demack, S., 2003). Benefits which can potentially be derived from POE offer an incentive which drives its deployment for many building owners as a matter of fact (Jaunzens, D., Grigg, P., Watson, M., Picton, E., 2003).

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

The process of post occupancy evaluation review evaluates and identifies any remedial work required, provides information to support continuous improvement for future project and can be an important part of the communication process for change management (Queensland, 2007). Furthermore, it focuses on the occupants' needs and measures the extent to which the building's outcome meets the occupants' expectations in relation to the safety qualities and importance of the residential environment and the functionality of the design; and the effectiveness of the design, construction, communication and occupancy process (Kooymans R., Haylock P. 2006), as cited by (Chikezie, C.E., 2014).

Origin and Development of Post Occupancy Evaluation

According to (Emuze *et al.,* 2013), POE is not a new model; it originated in the United Kingdom (UK) when the British Ministry of Education, in agreement with local governments, first undertook evaluations of buildings in the post-World War II period (Kooymans *et al.,* 2006). The United States of America (USA) followed in the footsteps of the UK, in the early 1960s, with the School Construction System Development in California. Internationally, POE has been endorsed on a longer-term basis as a useful addition to architectural practice in which the USA serves as an example in this regard (Kooymans *et al.,* 2006). Hence, POE gained momentum in the mid-1960s with an increase in the number of researchers focusing on building design (Emuze *et al.,* 2013).

In time, environmental psychologists developed interests in POE with the aim of focusing on scientific knowledge proliferation (Riley *et al.,* 2010). For instance, (Sheply, M.M., Zimmerman, K.N. & Boggess, M.M., 2009) conducted a POE study at the new location of a 174- person Architectural firm in Boston, USA. The study revealed that occupants were more satisfied with a new building when compared with an older building, although concerns were raised about the impact on indoor air quality, thermal comfort, lighting, noise and office layout (Shepley *et al.,* 2009), as cited by (Emuze *et al.,* 2013).

POE was derived from the "occupancy permit", a document that is issued once the building has been inspected and is declared free from all defects and ready for occupation (Riley *et al.,* 2010). During the early years of POE, academics decided to research the topic in-depth to determine the effectiveness of the POE because the profession of architecture had elected not to embrace POE as a field of study. According to (Riley *et al.,* 2010), POE was introduced as a result of complaints from the building occupants regarding problems such as: health and safety, security, disability, leakage, poor signage, lack of storage and privacy, halfway blockage, aesthetic shortcomings, inadequacy of designed space for equipment such as copier as well as the maintenance of glass surface such as skywalks (Chikezie, C.E., 2014).

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

POE is not a new concept; it has its origin in the UK when the British Ministry of Education in agreement with the local governments first undertook evaluation of buildings in the post-World War II period. The buildings assessed were mostly school buildings and thus resulted in a series of building performances official statement for schools in UK (Chikezie, C.E., 2014). The US followed in the footsteps of the UK during the early 1960s with School Construction System Development in California. Internationally, POE has been endorsed on a longer-term basis as a useful addition to architectural practice, for example, in the USA (Kooymans *et al.,* 2011). POE gained momentum in the mid-1960s with an increase in the number of researchers focusing on building design (Chikezie, C.E., 2014). As time went by, environmental psychology developed in the interest of POE with the aim of focusing on scientific knowledge (Riley *et al.,* 2010).

The term "POE" can be very misleading since it deals with the building once it has been completed and occupied, but in actual fact, it should be involved from the process of inception, through completion, until the occupation and post-occupancy stages (Riley *et al.,* 2010). During that time, researchers as noted by (Chikezie, C.E., 2014) started focusing on the relationship between users (occupants) and buildings. During the early 1970s, POE started to gain momentum when the focus shifted to the relationship between users of the building and their level of satisfaction (Chikezie, C.E., 2014). At that time, during the 1970s, it has been realized that most organizations were trying to adopt the POE as a strategic method for addressing the failure of many buildings. POE was also instituted with the primary objectives of addressing the health, safety and well-being of the occupants, as well as challenges in the building infrastructure (Riley *et al.*, 2010). Most researchers were still focusing on POE as a tool of finding satisfaction towards the late 1970s (Chikezie, C.E., 2014). During early 1980, POE started to dominate the public and private sectors, focusing on organizational effects on occupant satisfaction in the working environment (Khalil *et al.,* 2009).

The Purpose of Post Occupancy Evaluation

The purpose of POE is to systematically evaluate a designed and occupied setting from the perspective of those who use it (Walker, K., 2011). POE addresses the Indoor Environmental Quality (IEQ) and efficiency of the building performance with the aim of improving and obtaining maximum efficiency. POE is an evaluation tool that "demonstrates success and achievement of the objectives" (Watson, C., 2003). Once the evaluation has been conducted successfully, it will ultimately yield evidence of different perspectives, reflection and learning (Walker, K., 2011). POE is there to detect the performance failures of the existing office or residential building and to try to improve on the performance in future projects or future buildings. POE takes all these failures or challenges into account and reports back to the stakeholders so that new ways of improving building performance can be found (Chikezie, C.E., 2014).

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Using POE as a tool and interacting with the occupants will provide the organization with information about how the building performs (Chikezie, C.E., 2014). This useful information will be used as the benchmark when new or future projects start. It plays a very important role in the interaction between the users and the building, and is intended to be used for improving on the shortfall that exist within the existing building currently used by the occupants, POE also fulfils other objectives, such as identifying the building's defects as well as providing the design team with alternatives on how to prevent similar mistakes from happening in future projects. With POE in place, the quality of building management in the organization will be improved by using cons-effective strategic methods (Chikezie, C.E., 2014).

(Kirk S.J., Stirret C.M., 2011) define POE "as part of value engineering that continuously improves the facilities in the building". On the one hand, POE started to function on its own while on the other hand, moving away from the architectural point view. By that time, the POE was being used based on the occupants' needs, as the building performance is judged on the based on the user satisfaction needs and IEQ. The intention of the POE is to improve the quality of the building and to identify the problems that can be used as benchmarks so that previous mistakes and unwanted features are not included or repeated in future projects. Occupant satisfaction with the building is associated with the efficiency of building performance. If the Indoor Environmental Quality (IEQ) is not of a high standard, the occupants will be dissatisfied with the results they get from the building (Chikezie, C.E., 2014).

(Nawawi *et al.,* 2008) define POE as a systematic evaluation of opinion about buildings in use, from the perspective of the people who use them. Therefore, POE is concern with building performance so as to satisfy occupants with regard to noise control. Implementing POE in an organization will help to identify measurable link between the building quality and performance outcomes of the occupants. POE is so crucial to be conducted because it indicates how well building performance works in order to satisfy the occupant's needs and organizational goals. To sum up the above mentioned, POE provides structured review of the process of delivering a project as well as a review of the operational, functional and strategic performance of the building during occupation. POE provides feedback on the performance of the building throughout its service life (Chikezie, C.E., 2014).

Indoor Environmental Quality (IEQ)

The term "indoor environmental quality" (IEQ) represents a domain that encompasses diverse sub-domains that affect the human life inside a building. These include indoor air quality (IAQ), lighting, thermal comfort, acoustics, drinking water, ergonomics,

electromagnetic radiation, and many related factors (Almeida RMSF, de Freitas VP, Delgado JMPQ, 2015), as depicted in the Figure below:

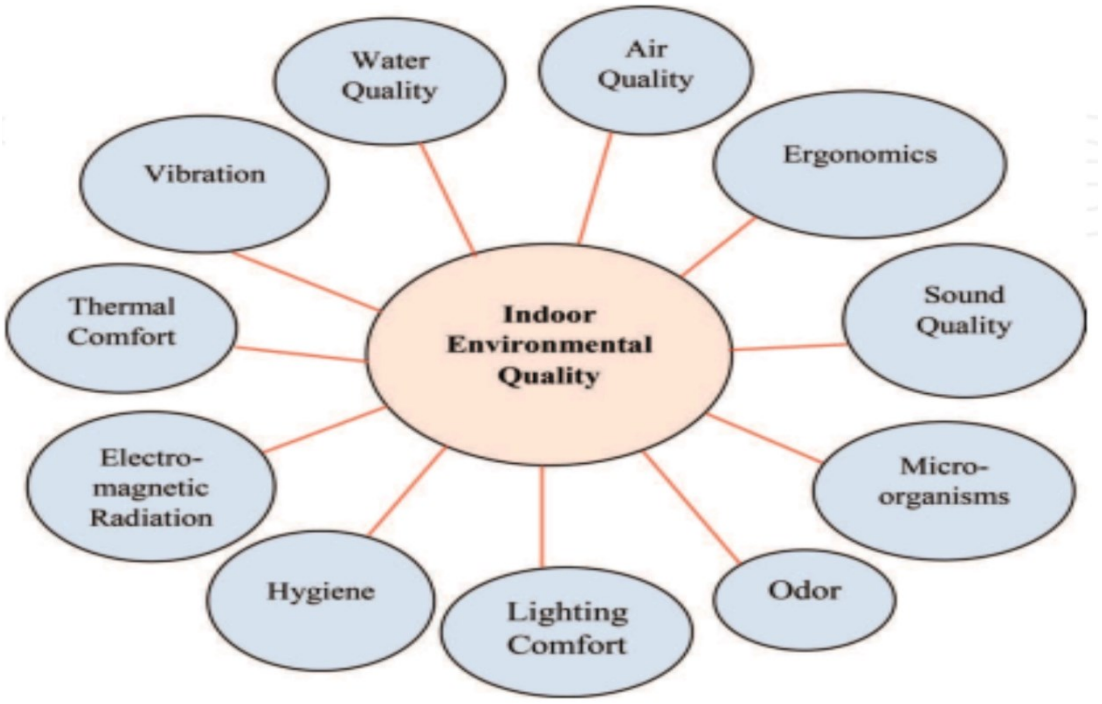

Figure: IEQ Components.

Enhanced environmental quality can improve the quality of life of the occupants, increase the resale value of the building, and minimize the penalties on building owners (Muhammad Abdul Mujeebu, 2019).

IEQ in offices and other workplaces has a crucial role on the return on investment of businesses. A workplace with high IEQ obviously improves the workers' health and mood, thereby increasing their productivity. Therefore, the additional cost of maintaining high IEQ levels in workplaces will be paid back in a reasonable period and generates additional monetary returns thereafter (Muhammad Abdul Mujeebu, 2019). It should be noted that buildings being rated as "sustainable and green" do not truly guaranty their compliance with the desired IEQ level (Steinemann A., Wargocki P., Rismanchi B., 2017). Therefore, IEQ should be given specific focus while designing new buildings as well as in building retrofit plans (Muhammad Abdul Mujeebu, 2019).

Indoor Air Quality (IAQ)

Indoor air quality (IAQ), which depends on airborne contaminants inside a building (or in a broader sense, any other enclosure such as a vehicle or an animal house), is one of the

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

crucial factors that determine the quality of the indoor environment. Providing adequate air quality for the occupants is one of the most important functionalities of a building. Lung cancer (due to radon), Legionnaires' disease, carbon monoxide poisoning, allergy, and asthma are among the serious health implications of poor IAQ (Persily AK, Emmerich SJ, 2012). The "sick building syndrome" resulting from inadequate levels of IAQ significantly affects the health and productivity of office employees (Al horr Y., Arif M., Katafygiotou M., Mazroei A., Kaushik A., Elsarrag E., 2016). Though tremendous efforts are in progress to realize energy-efficient, green, and sustainable buildings, maintaining a safe level of IAQ in these buildings is an ongoing challenge. This is due to the fact that many energy-efficient measures in a building (such as reduced outdoor air ventilation rate, increased thermal insulation, and efficient cooling equipment) can have a detrimental impact on IAQ. Thus, alongside energy efficiency and sustainability, there has been a growing concern over air pollution inside buildings. Therefore, attempts to ensure energy efficiency and sustainability in buildings should simultaneously ensure enhanced health, comfort, and productivity of the occupants (Persily *et al.,* 2012).

There are two major approaches to tackle IAQ issues in buildings: one is to increase the ventilation rate of outdoor air into the building, and the other is to minimize or control the sources of air pollution within and outside the building. Having said that, the first strategy would work only when the outdoor air is clean enough to improve IAQ (Al horr *et al.,* 2016). The various sources that affect IAQ are, but not limited to, volatile organic compounds, biological pollutants, oxides of carbon and nitrogen, particulate matter, tobacco smoke, radon, mould, formaldehyde, pesticides, and combustion products. (Heseltine E., Rosen J., 2009) outlined health issues associated with building moisture and biological agents, and the most important health problems identified are respiratory symptoms, allergies, asthma, and perturbation of the immunological system. A review (Becher R., Øvrevik J., Schwarze PE, Nilsen S., Hongslo JK, Bakke JV, 2018) has revealed that carpets play a crucial role in IAQ, as they act as a sink for indoor air pollutants such as particles, allergens, and other biological pollutants.

Thermal comfort

The term "thermal comfort" refers to a condition that is governed by many environmental and human factors; in other words, physiological, physical, and sociopsychological factors. The environmental factors include air temperature, air velocity, humidity, radiant temperature, and relative humidity, while the major human factors are clothing and metabolic heat. The various other factors include physical health, mental condition, availability of food and drink, and acclimatization. This condition is mostly subjective, which cannot be directly quantified. It has been established that the

thermal comfort level is acceptable if at least 80% of the occupants feel comfortable with it (Muhammad Abdul Mujeebu, 2019).

Lighting comfort

Visible light falls in a narrow range in the electromagnetic spectrum, between ultraviolet and infrared wavelength ranges. Light has both particle and wave properties; when treated as a wave, light has a frequency that depends on the colour of the struck surface. For instance, white surface reflects back most of the incident light, while a black surface absorbs most of it. The main aspects of lighting comfort are light level (intensity or brightness), contrast, and glare. The light intensity requirement depends on the type of activity in the building; for instance, operating rooms need a brighter level than living rooms. The term "contrast" refers to the ease of understanding or legibility; higher contrast gives higher clarity (e.g., black text on white paper provides the highest contrast). Glare is always undesirable as it causes a high level of discomfort in viewing the objects and affects the retina (Muhammad Abdul Mujeebu, 2019).

The visual comfort level is evaluated by means of some established glare metrics or indices; for example, glare probability (DGP) and daylight glare index (DGI) are used for assessing discomfort due to daylighting, while unified glare index (UGI), visual comfort probability (VCP), and CIE glare index (CGI) are employed for measuring the discomfort level of artificial lighting (Suk JY, 2019).

Acoustic comfort

Building acoustics deals with controlling the quality of sound inside a building. It has two parts, namely, room acoustics and building acoustics, which deal with the sound propagation within a room and between rooms (through walls, doors, and floors), respectively. While the room acoustics focuses mainly on the sound quality (e.g., easy communication and high level of intelligibility in office spaces), the building acoustics is concerned with the "unsolicited" sound (e.g., the noise in a room should not be a nuisance to other rooms). The acoustic comfort in a building has a crucial impact on the health, well-being, communication, and productivity of the occupants. The acoustic comfort can be affected by factors such as the geometry and volume of a space, generation of sound within or outside the space, airborne noise transmission, impact noise, and the acoustic characteristics (absorption, transmission, and reflection of sound) of the interior surfaces. The measuring unit of sound intensity is decibels (dB), and of sound pitch is hertz (Hz). The comfortable range of sound for humans is typically 20–20,000 Hz (Muhammad Abdul Mujeebu, 2019).

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

The common parameters used for evaluating the acoustic performance of a building are reverberation time (RT), sound pressure level (SPL), early decay time (EDT), clarity (C50 for speech and C80 for music), sound definition or speech intelligibility (D or D50), and speech transmission index (STI). RT is defined as the time for the sound level to decay by 60 dB after a sound source has been switched off. EDT is similar to RT, but it is the initial rate of sound decay in a room, measured as the slope of a line 0–10 dB decay below the maximum sound level. D50 is defined as the ratio of the early received sound energy (0–50 ms after direct sound arrival) to the total received energy. Clarity is defined as the ratio of the energy in the early sound (received in the first 80 ms) to that in the reverberant sound. STI is a measure of speech transmission quality, which indicates the degree to which a transmission channel degrades speech intelligibility. STI ranges from 0 to 1; a speech transferred through a channel with STI of 1 is perfectly intelligible, but the intelligibility reduces as the STI approaches zero. International standards and guidelines (e.g., ISO 18233) are available for the measurement of these characteristics (Muhammad Abdul Mujeebu, 2019).

Ergonomics

Ergonomics deals with the design of objects, systems, and environment, in a manner that ensures human comfort. In fact, ergonomics encompasses all components of IEQ, simply because the prime objective of IEQ is human health and comfort. It covers diverse disciplines such as anatomy, physiology, psychology, and design. An indoor ergonomist should be specialized in the interrelationship between the human mind and body and the various aspects of a building such as architecture, interior design, building services, structure, materials, and microclimate. In general, environmental ergonomics deals with the interaction between people and their physical environment with particular importance on thermal comfort, lighting, noise, and vibration. Similar to ergonomics in a residential environment, ergonomics in offices and workplace is also a scientific discipline and a topic of research (Muhammad Abdul Mujeebu, 2019).

Electromagnetic field and radiation

Electromagnetic field is created by moving electric charges, microwaves, radio waves, electrical currents, and transformers. The low-frequency electromagnetic radiation prevailing mostly in indoors (due to electrical appliances, computers, wireless devices, etc.) can have detrimental effect on human health, and there are international regulations to deal with this problem (e.g., International Radiation Protection Association (IRPA)) (Fayed I., Bedda M., 2015). Most of the regulations agree that exposure to electromagnetic field beyond the safe range of 0–300 Hz is harmful for the human body

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

(Valberg PA, van Deventer TE, Repacholi MH, 2007). The possibility of health hazards such as acute lymphoblastic leukemia in children due to electromagnetic field exposure was well established decades ago (Linet MS, Hatch EE, Kleinerman RA, Robison LL, Kaune WT, Friedman DR, 1997).

Water quality

Adequate, safe, and accessible supply of drinking water is vital for the sustenance of human life especially in indoor environments where access to natural sources of water such as wells, ponds, rivers, and lakes is limited. Drinking water quality has a direct impact on human health. Infants, young children, weak and elderly people, and those who live in unhygienic environment are largely prone to waterborne deceases (WHO, 2006). There is no universally applicable legislative framework for the implementation of standards to maintain drinking water quality. An approach that works in one country or region may not be suitable for other countries. Therefore, each country should develop its own legislation according to its requirements and capacity for implementation. However, while developing standards, the most common aspects that need to be taken into account are microbial safety, chemical safety, radiological safety, disinfection, and acceptability (WHO, 2006).

REFERENCES

J.A. Clarke, J.L.M. Hensen (2015). Integrated building performance simulation: Progress, prospects and requirements, Building and Environment, Volume 91, Pages 294-306.

Pieter de Wilde (2019). Ten questions concerning building performance analysis, Building and Environment, Volume 153, Pages 110-117.

Kostantinos Gobakis, Dionysia Kolokotsa (2017). Coupling building energy simulation software with microclimatic simulation for the evaluation of the impact of urban outdoor conditions on the energy consumption and indoor environmental quality, Energy and Buildings, Volume 157, Pages 101-115.

Siyue Guo, Da Yan, Shan Hu, Yang Zhang (2021). Modelling building energy consumption in China under different future scenarios, Energy, Volume 214, 119063.

N. Khalil, H.N. Husin (2009). Post Occupancy Evaluation towards Indoor Environment Improvement in Malaysia's Office Buildings. Journal of Sustainable Development, vol. 2, no.1, 186–191.

D. Erten, K. Henderson, B. Kobas (2009). A Review of International Green Building Certification Methods: A Roadmap for Certification System in Turkey. Fifth International Conference on Construction in the 21st Century (CITC-V) "Collaboration and Integration in Engineering, Management and Technology". Istanbul. Turkey.

D. Yan, W. O'Brien, T. Hong, X. Feng, H. Burak Gunay, F. Tahmasebi, A. Mah-davi (2015). Occupant behaviour modelling for building performance simulation: current state and future challenges, Energy Build. 107 264–278.

Bart Poel, Gerelle van Cruchten, Constantinos A. Balaras (2007). Energy performance assessment of existing dwellings, Energy and Buildings, Volume 39, Issue 4, Pages 393-403.

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Luis Pérez-Lombard, José Ortiz, Rocío González, Ismael R. Maestre (2009). A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes, Energy and Buildings, Volume 41, Issue 3, Pages 272-278.

Mohammad Saad Al-Homoud (2001). Computer-aided building energy analysis techniques, Building and Environment, Volume 36, Issue 4, Pages 421-433.

Shengwei Wang, Chengchu Yan, Fu Xiao (2012). Quantitative energy performance assessment methods for existing buildings, Energy and Buildings, Volume 55, Pages 873-888.

Aliyu Ahmad Aliyu, Maryam Salihu Muhammad, Mohammed Girgiri Bukar, And Ibrahim Musa Singhry (2016). An evaluation of occupants' satisfaction and comfort with housing facilities: literature analysis and future research opportunities, Proceedings of the Academic Conference on Agenda for Sub-Sahara Africa Vol. 4 No. 3.

Behlou, M. (1991), Post Occupancy Evaluation of Five Storey Walk Up Dwellings: The Case of Four Mass Housing Estates in Algiers, Unpublished PhD Dissertation, Department of Architectural Studies, University of Sheffield, U.K.

Murat Mirata, Tareq Emtairah (2014). Water Efficiency Handbook: Arab Forum for Environment and Development (AFED), Published in cooperation with Technical Publications/ Al-Bia Wal Tanmia magazine, Beirut, Lebanon.

AQUASTAT (2008). Irrigation in the Middle East Region in Figures. Food and Agricultural Organization (FAO), Rome.

Zimring, C.H. & Reizenstein, J.E. (1980). Post Occupancy Evaluation: An Overview, In Environment and Behavior, 12(4), pp: 429-450.

Preiser, W.F.E., Rabinowitz, H.Z., & White, E.T. (1988). Post Occupancy Evaluation, New York: Van Nostrand Reinhold.

Woon, N,B., Mohammad, I.S., Baba, M. & Nazri, N.Z.A. (2015). Critical Success Factors for Post Occupancy Evaluation of Building Performance: A Literature Analysis, Jurnal Teknologi (Sciences & Engineering) 74(2), pp: 41-49.

Nawawi, A.H., & Khalil, N. (2008). Post Occupancy Evaluation Correlated with Building Occupants' Satisfaction: An Approach to Performance Evaluation of Government and Public Buildings, Journal of Building Appraisal, 4(2): 59–69.

Hewitt, D., Higgins, C., Heatherly, P. & Turner, C. (2005). Market-Friendly Post Occupancy Evaluation, New Building Institute, Portland, Building Performance Report, Number: c.10091.

Chikezie, C.E. (2014). Post Occupancy Evaluation of Building in South Africa: A Case Study of Sophiatwon Student Residence, Johanessburg, Unpublished M.Sc Dissertation.

Riley, M., Kokkarinen, N. & Pitt, M. (2010). Assessing Post Occupancy Evaluation in Higher Education Facilities, Journal of Facilities Management, 8(3), pp: 202-213.

Carthey, J. (2006). Post Occupancy Evaluation: Development of a Standardized Methodology for Australian Health Projects, The International Journal of Construction Management, 2(4), pp: 57-74.

Jaunzens, D., Grigg, P., Watson, M., & Picton, E. (2003). Building Performance Feedback: Getting Started, BRE Digest 478, BRE Bookshop, London, UK.

Queensland Housing Affordability Strategy, (2007). Queensland Government, Office of Urban Management, Department of Infrastructure.

Kooymans, R. & Haylock, P. (2006). Post Occupancy Evaluation and Workplace Productivity. In: Proceedings of the Pacific Rim Real Estate Society Conference, 22 January 2006, Auckland, New Zealand, pp. 1-15.

Emuze, F., Mashili, H. & Botha, B. (2013). Post Occupancy Evaluation of Office Buildings in a Johannesburg Country Club Estate, Act a Structilia, 20(1), pp: 89-110.

Pinder, J. Price, I., Wilkinson, S.J. & Demack, S. (2003). A Method for Evaluating Workplace Utility, Property Management, 21(4), pp: 218-229.

EDITOR-IN-CHIEF
Prof. W. F. HILL [MALAWI]

Sheply, M.M., Zimmerman, K.N. & Boggess, M.M. (2009). Architectural Office Post-occupancy Evaluation, Journal of Interior Design, 34(3), pp: 17-29.

Walker, K. (2011). Developing a Site Evaluation Framework for Ephemeral Festivals and Events: A Study of Hillside Festival, Unpublished M.Sc Dissertation, University of Guelph.

Watson, C. (2003). Review of Building Quality Using Post Occupancy Evaluation, Journal of Programme Educational Building, 3(5), pp: 1-5.

Kirk, S.J. & Stirret, C.M. (2011). Post Occupancy Evaluation for Added Valuation at Trail's End, In: Lean Construction Institute of Michigan State University, USA: 1-17.

Muhammad Abdul Mujeebu (2019). Department of Building Engineering, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia.

Almeida RMSF, de Freitas VP, Delgado JMPQ (2015). School buildings rehabilitation-indoor environmental quality and enclosure optimization. School Buildings Rehabilitation. Switzerland AG: Springer Nature; pp. 5-17.

Steinemann A. Wargocki P. Rismanchi B. (2017). Ten questions concerning green buildings and indoor air quality. Building and Environment.;112(2017):351-358.

Persily AK, Emmerich SJ (2012). Indoor air quality in sustainable, energy efficient buildings. HVAC & R Research;18(1-2):4-20.

Al horr Y., Arif M., Katafygiotou M., Mazroei A., Kaushik A., Elsarrag E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. International Journal of Sustainable Built Environment;5(1):1-11.

Heseltine E., Rosen J. (2009). WHO Guidelines for Indoor Air Quality: Dampness and Mould. Germany: World Health Organization Regional Office for Europe.

Becher R., Øvrevik J., Schwarze PE, Nilsen S., Hongslo JK, Bakke JV (2018). Do carpets impair indoor air quality and cause adverse health outcomes: A review. International Journal of Environmental Research and Public Health. 15(2): E184.

Suk JY (2019). Luminance and vertical eye illuminance thresholds for occupants' visual comfort in daylit office environments. Building and Environment; 148:107-115.

Fayed I, Bedda M (2015). Electromagnetic radiation and its effects on human beings: Survey and environmental recommendations. In: 15th Scientific Symposium for Hajj, Umrah and Madinah visit—Scientific Portal for 1436AH; 27-28 May 2015; Saudi Arabia. pp. 35-47.

Valberg PA, van Deventer TE, Repacholi MH (2007). Workgroup report: Base stations and wireless networks- - radiofrequency (RF) exposures and health consequences. Environmental Health Perspectives.;115(3):416.

Linet MS, Hatch EE, Kleinerman RA, Robison LL, Kaune WT, Friedman DR (1997). Residential exposure to magnetic fields and acute lymphoblastic leukemia in children. The New England Journal of Medicine.;337(1):1-8.

W.H.O. Guidelines for Drinking Water quality: First Addendum to Third Edition, Vol 1—Recommendations. Geneva, Switzerland: World Health Organization; 2006.

National Institute of Building Sciences. (2010). Sustainable. Retrieved May 1, 2011, from http://www.wbdg.org/design/sustainable.php.

Suk-Kyung Kim, Ying Hwang, Young S. Lee, & William Corser (2015). Interior Design Program, School of Planning, Design, & Construction, Michigan State University, Institute for Health Policy, College of Human Medicine, Michigan State University, USA.

US Green Building Council. (2014). LEED for Healthcare Projects. Retrieved September 1, 2014, from http://www.usgbc.org/projects/healthcare.