

Investigating the Impact of Daylighting Strategies on Energy Efficiency and Occupant Comfort in Buildings

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Abstract:

This study paper's "Discussion" section sets out on a trip through the complex interactions between architectural design, energy efficiency, and occupant well-being, as made clear by a qualitative inquiry into the effects of daylighting systems in buildings. A seamless fusion between sustainable design and the human experience is revealed by the findings' analysis. The importance of daylighting solutions in attaining energy efficiency is shown by key discoveries. It has long been known that using natural light is wise, and building occupants and stakeholders have repeatedly reported considerable savings in power use for lighting. Automated controls have become essential partners in energy efficiency optimisation while adapting to changing daylight circumstances and user preferences. A complex balancing act was needed to achieve this balance, and crucial instruments were user control, architectural design, and behavioural modifications. The debate emphasises the significant impact of daylighting on occupant comfort in addition to energy savings. Natural light's calming, diffused nature has been called a salve for the soul since it promoted visual relaxation. The presence of psychological comfort was also noticeable, with residents expressing accounts of enhanced moods, increased motivation, and general happiness fostered by well-lit settings. Our investigation confirms the beneficial effects of natural light on visual comfort and productivity, which are supported by well-established theories in environmental psychology and ergonomics. Additionally, it supports recent research that connects interior surroundings to mental health by providing anecdotal evidence for these associations. The talk ends by pointing to possible futures. Long-term daylighting impacts, climate-responsive architecture, and the incorporation of cutting-edge technology all beckon as unexplored domains that provide fertile ground for invention and discovery.

Keywords — Daylighting Strategies; Energy Efficiency; Occupant Comfort; Comforts; Buildings

I. INTRODUCTION

The importance of daylighting solutions has become a key area of architectural and environmental design in the quest to build more sustainable and human-centric built environments [1]. The various findings of our qualitative analysis into how daylighting methods affect energy efficiency and occupant comfort in buildings are braided together in this research paper as a place for reflection and interpretation. We set out on a trip across the many facets of sustainability, human experience, and design as we follow the contours of this conversation.

A complex tapestry of ideas gleaned from our qualitative investigation forms the basis of this discussion's synthesis of findings. The conclusions serve as a symbol of how design, energy efficiency, and psychology interact [2]. They make daylighting solutions' effects on the built environment's physical and psychological aspects clear. The qualitative information supports the significant influence of daylighting schemes on energy efficiency [3]. As residents and other interested parties conversed, a common story evolved that resonated with accepted ideas about using natural light to lessen the requirement for artificial lighting. Automated

controls have become the saviours of optimisation, painstakingly adapting to constantly changing user preferences and lighting circumstances.

The extensive impact of daylighting on occupant comfort is also revealed in this section. With its gentle, diffused character being compared to a calming balm, visual comfort was clearly the desired objective [4]. The discussion's underlying theme was psychological comfort, which came to the fore when residents related stories of how well-lit places had a positive impact on their emotions, motivation, and general well-being. However, the synthesis depicts a precarious balancing act. It becomes obvious how difficult it is to develop daylighting plans that simultaneously maximise energy efficiency and occupant comfort. This canvas is painted with a variety of high-quality brushes, and it is this canvas that architectural design, user control, and behavioural adjustments all contribute to the development of a pleasing equilibrium [5]. We map our journey within the framework of the current literature as we dive into the synthesis, which is a rich and developing discourse on daylighting, building performance, and human well-being. The themes of our qualitative investigation are consistent with the body of knowledge, adding harmony and depth to this symphony of ideas.

Our results are consistent with earlier quantitative research that calculated the potential energy savings from daylighting techniques. Nonetheless, the qualitative strokes give the painting depth by capturing the sensory elements that quantitative measures by themselves are unable to capture. Regarding the beneficial effects of natural light on visual comfort and productivity, there is a clear resonance with known ideas in environmental psychology and ergonomics. The value of these ideas is attested to by our qualitative insights, which are vivid and personal.

Additionally, the results are consistent with recent studies that shed light on the relationship between interior settings and mental health. To show the kaleidoscope of tenants' well-being, qualitative data operate as prisms, reflecting their subjective

experiences. The theoretical landscape of building design, energy efficiency, and occupant well-being is explored in our conversation, which goes beyond the domain of the empirical. Our research contributions resonate in this environment like resonant notes, integrating with accepted ideas and paving fresh avenues. Our study praises the benefits of qualitative research in the field of architectural design. It highlights the need of comprehending architecture's sensory components in addition to its quantitative pursuit of performance measures. The fundamental ideas of daylighting shine with fresh relevance in the wake of our discoveries. In doing so, they highlight the practical wisdom of these concepts by showing up in the experiences of building inhabitants. Our findings strongly support the significance of user-centric design methodologies. They act as a clarion cry, reminding us that the requirements, preferences, and behaviours of the occupants should be the driving force behind design choices.

II. LITERATURE REVIEW

A. Daylighting Strategies and Energy Efficiency

The capacity of daylighting methods to capture natural light, which reduces the demand for artificial lighting and, as a result, energy consumption [6], is a crucial feature of these systems. Studies in this field focus on the energy savings that may be achieved with good daylighting design. Researchers have looked at the ways in which techniques like dynamic shading systems, light redirection, and daylight harvesting might help minimise the amount of power used. These findings highlight the significance of incorporating daylighting into environmentally friendly architectural practises, in line with international initiatives to cut greenhouse gas emissions and battle climate change [7]. The energy savings related with daylighting solutions have been assessed through quantitative research, which has shown significant drops in lighting and cooling loads [8]. To evaluate how various daylighting approaches affect a building's energy efficiency, several studies have used energy simulation models. The experiences of building occupants and the practical difficulties of adopting

daylighting solutions in real-world settings might be illuminated by qualitative insights, which are necessary to supplement these quantitative findings.

B. Daylighting Strategies and Occupant Comfort

A major subject in studies on occupant well-being is the effect of natural light on visual comfort. Numerous research have examined how glare, contrast, and colour rendering impact visual comfort in relation to daylighting. According to research, well-designed daylighting systems can improve visual comfort, lessen eye strain, and increase general contentment among building occupants [9]. An in-depth understanding of the complex interaction between architectural design and human perception has been gained via qualitative examinations into occupants' subjective experiences and preferences with regard to daylight. The psychological wellbeing of residents is significantly impacted by daylighting in addition to visual comfort

[10]. In-depth analysis of the emotional and cognitive components of occupant comfort is done in this field using qualitative research. In order to understand how connected people feel to the outside world, how they feel, and how productive they are in daylit areas, interviews and questionnaires have been employed [11]. According to these research, daylighting has the potential to provide more enjoyable and stimulating interior settings, which would enhance inhabitants' mental health and productivity.

C. Previous Research on Daylighting

This part also looks at the current corpus of work on daylighting [12] to get a full knowledge of the research environment. It divides prior research into quantitative and qualitative study, showing the advantages and disadvantages of each methodology. A greater understanding of occupant experiences, preferences, and behaviours may be gained via qualitative research, which complements quantitative studies' useful data on energy savings [13]. This review emphasises the necessity for a balanced approach in the research of daylighting

tactics while also recognising the complementarity of various methods.

III. METHODOLOGY

The systematic strategy used to examine how daylighting schemes affect energy efficiency and occupant comfort in buildings is described in the study methodology part of this work. This part offers openness and rigour in the research process with a thorough discussion of the study design, data collection strategies, sample methodologies, data analysis methods, and ethical issues.

This study employs a qualitative research methodology since the authors feel it is most suited for examining the complex and context-specific facets of daylighting techniques in building design. When doing qualitative research, it is possible to gain a thorough knowledge of how building occupants feel, perceive, and act in response to daylighting treatments. It enables the gathering of detailed descriptive information that goes beyond measurable metrics and statistical correlations.

A case study approach is used in the qualitative research paradigm. With the help of this methodology, it is possible to thoroughly examine a small number of examples, each of which represents a distinct setting in which daylighting strategy execution takes place. The case study methodology enables a comprehensive analysis of the interactions between occupant comfort and energy efficiency in particular architectural contexts. Additionally, it makes it easier to look at context-dependent variables and real-world complexity.

A. Data Collection

The main technique of gathering data for this study is semi-structured interviews. Interviews are conducted with building occupants, facility managers, and design experts connected to the chosen examples to glean qualitative information about their perspectives and experiences with daylighting techniques. It is encouraged for participants to openly share their views, opinions, and observations by using open-ended questions. For the sake of accuracy in data analysis, interviews are taped and typed out. In addition to conducting

interviews, we also make direct inspections of the chosen building locations. The use of shade, lighting levels, glare, and occupant responses to natural light are all factors that researchers keep track of. Observations add crucial background and support the triangulation of interview findings.

Analyses of documents are done in addition to observations and interviews. To learn more about the proposed daylighting techniques and the thinking behind their design, pertinent papers such as architectural drawings, daylighting design studies, and building performance data are examined. Understanding the original design intent through document analysis enables for comparisons with actual results.

B. Sampling Strategy

In this study, a purposive sampling procedure was used to choose the participants. Cases are chosen based on a set of requirements, such as whether daylighting tactics have been put into practice, the variety of building types, the locations, and the architectural styles. In order to enhance the study's findings and make it easier for qualitative insights to be applied to a wider context, it is important to collect information from a variety of situations and experiences.

C. Data Analysis

An approach to theme analysis is used in data analysis. To find recurrent themes and patterns, relevant documents, transcriptions of interviews, observational notes, and interviews, and other data are thoroughly coded. The construction of a framework for coding that changes when new insights are discovered is a step in the iterative coding process. By organising and interpreting qualitative data, thematic analysis enables researchers to find relevant findings and solutions to their research concerns.

A key component of this research is the "Case Selection and Description" section, which establishes the groundwork for a detailed examination of how daylighting tactics affect energy efficiency and occupant comfort. For the validity, applicability, and depth of the findings to be guaranteed, the case study locations must be carefully chosen, as well as their architectural elements well described.

A. Selection Criteria

A set of stringent criteria that aim to include a broad spectrum of experiences and circumstances serve as the basis for case selection:

The existence of daylighting solutions within the structure is the main factor considered when choosing a case. By using this criterion, it is ensured that the examples are closely related to the study's goals and that the effectiveness of these tactics can be examined in more detail. Cases are purposefully picked from a variety of building types to give a thorough knowledge of daylighting's effects. Commercial structures, educational institutions, and housing are among examples. Variations in user behaviors, building designs, and occupancy patterns are all taken into consideration by this variety. The study acknowledges the impact of regional architectural styles, sun exposure, and weather on daylighting solutions. To represent this variation, instances are chosen from a range of geographical locations and climatic zones.

When choosing a case, the selection process takes into account variations in architectural design aspects such as building size, layout, orientation, and design characteristics. This variety makes it easier to examine how various design features and daylighting tactics interact. Certain examples are selected based on their sustainability certifications, such as LEED or BREEAM. This addition enables an investigation of the role daylighting plays in accomplishing sustainability objectives and fulfilling certification requirements.

IV. CASE SELECTION AND DESCRIPTION

Case Study Sites

Site 1: Commercial Office Building

Architectural Details: The case study site has a contemporary office structure that is distinguished by a dramatic glass front that is intended to optimize natural light penetration. Advanced daylighting techniques are used in the building, such as automatic shade systems and a light redirection system. The distribution of daylight throughout the workstation is optimized using these characteristics. Because of the building's location in a temperate temperature zone and the seasonal fluctuations in sunshine exposure, it is an interesting object of study.

Site 2: Educational Institution

Architectural Details: The second case study location is a campus building of an educational institution, a mid-sized university. It incorporates a variety of daylighting techniques, including skylights, light shelves, and internal glass, all of which are purposefully placed to provide natural light into the common spaces and classrooms. The building has special possibilities and challenges in utilizing natural light to improve energy efficiency and occupant comfort due to its location in a sunny area.

Site 3: Residential Apartment Complex

Architectural Features: The third case study focuses on an apartment building complex with a number of structures that have various orientations. Large windows and balconies are a feature of every apartment in the complex, which helps inhabitants stay well-lit by allowing in plenty of natural light. Due to the complex's urban location, it is important to take into account occupant comfort and energy efficiency in settings with large densities of people.

Building Descriptions

It includes a thorough description of the particular daylighting techniques that were included into the building design. This contains information on any cutting-edge lighting methods used to maximize natural light, such as skylights, light shelves, shading mechanisms, and glass kinds. Documentation is present on the structure's design, orientation, and

spatial arrangement. In influencing how daylight enters and interacts with interior areas, these factors are crucial. The use of HVAC systems, insulation, and renewable energy sources are only a few examples of other energy-saving features and technologies that are highlighted. The comprehensive evaluation of energy efficiency must take these characteristics into account. It is recorded how many people are using the building's areas and how they use those spaces. Inhabitant comfort and energy use can be greatly impacted by occupancy density. The surrounding environment of the building is taken into account, including things like its distance from other buildings, the landscaping, and the climate in the area. The efficiency of daylighting solutions and occupant experiences may be affected by several environmental considerations.

This section makes sure that readers have a clear knowledge of the various settings in which daylighting solutions are explored by giving thorough explanations of the case study locations that were chosen. The ensuing data collecting, analysis, and interpretation will take place against the backdrop of these descriptions.

Impact on Energy Efficiency

The influence of daylighting schemes on energy efficiency is clearly understood thanks to the qualitative analysis of the data. Several significant conclusions are drawn: When daylighting tactics were properly implemented, building occupants and facility managers routinely saw considerable drops in the amount of power used for illumination. The ideas of utilizing natural light to lessen the requirement for artificial lighting are in line with this insight. According to the results of interviews, automated controls for lighting and shading were essential for maximizing energy efficiency. These devices' adaptability to shifting lighting conditions and user choices was well-liked by the occupants. Qualitative information provide light on how residents changed their behavior in response to daylighting. Many claimed to have been more conscious of natural light, frequently altering their blinds or drapes to best take use of it. The energy savings were a result of these behavioral modifications.

Residents in this instance stressed striking a balance between enhancing natural light and reducing glare. Even though they valued the energy savings, they observed that the shade control settings occasionally needed to be adjusted owing to glare discomfort. The daylighting tactics employed by the educational institution, according to the findings, resulted in considerable energy savings. Occupants were pleased with how well-lit the classrooms were, saying that this improved the atmosphere for learning. The apartment complex's residents emphasized the value of daylight in lowering power costs and raising the standard of their homes overall. The majority of residents adopted new behavioral patterns, such as preferring to read in the sunlight.

Influence on Occupant Comfort

The qualitative study explored how building inhabitants felt about how daylighting affected their comfort, asking them about their thoughts and experiences. The ease of their visual perception in daylight environments was repeatedly praised by users. They characterized natural light's calming and aesthetically pleasant soft and diffused aspect as adding to a feeling of well-being. According to interviews, daylighting significantly affected residents' emotions and general psychological wellbeing. People who were exposed to natural light claimed to feel more at ease, sharp, and satisfied. Qualitative research revealed that well planned daylighting solutions enhanced residents' creativity and productivity. The commercial office building's employees reported higher work satisfaction, and the educational institution's students felt more invested in their studies.

Employees who worked in regions with plenty of daylight reported higher levels of job satisfaction and lower levels of stress. The majority of respondents agreed that sunshine has a beneficial effect on wellbeing, despite a few mentioning occasional glare problems. In classrooms that had lots of natural light, students said they felt at ease and were more motivated. They attributed the appealing and helpful learning environment that daylighting created. The benefits of sunshine on daily activities and mental health were underlined by the residents. The feeling

of being connected to nature and its beneficial effects on people's general happiness were praised by many.

Interactions between Energy Efficiency and Comfort

Qualitative research showed how energy efficiency and occupant comfort are intricately intertwined. According to the results of the interviews, there may be a fine line to walk when maximizing daylighting for both energy efficiency and occupant comfort. Energy-saving strategies occasionally made it harder to be comfortable in terms of heat or brightness.

Balancing energy efficiency and comfort relied heavily on occupants' management of daylighting systems, including blinds and curtains. Greater happiness was indicated by those who had more control alternatives. The layout of windows and the usage of architectural features like light shelving all had a direct bearing on the buildings' energy efficiency and comfort. Cases that have well chosen architectural design features frequently achieved a pleasing equilibrium.

Synthesis of Findings

Insights about the qualitative effects of daylighting schemes on energy efficiency and occupant comfort are included in the findings synthesis. It includes the following salient points:

The qualitative information supported the notion that daylighting techniques have a major influence on energy efficiency. The amount of power used for lighting in well-lit places was consistently reported by building occupants and stakeholders. Automated controls were crucial to maximizing energy efficiency since they made sure that natural illumination was used as little as possible and harnessed properly.

The vast majority of the data are in favor of daylighting's beneficial effects on occupant comfort. Natural lighting, which was gentle and calming, contributed to the overall feeling of visual comfort. In well-daylit surroundings, occupants reported increased moods, motivation, and general contentment, which had a favorable influence on their psychological comfort and well-being.

When developing daylighting techniques, a delicate balance is necessary, as the qualitative data highlighted. While increasing energy efficiency is important, there are occasionally problems with glare or thermal comfort that arise. A harmonic balance was attained thanks in large part to occupant control of daylighting systems and careful consideration of architectural design.

The discussion also places the results in relation to earlier research on daylighting, building efficiency, and occupant well-being. There are a few noteworthy points: The qualitative results are consistent with earlier quantitative research that showed how daylighting measures might reduce energy use. Qualitative research, however, provides richness by capturing the experience and behavioral characteristics of residents.

Environmental psychology and ergonomics have long-held notions that are consistent with the beneficial effects of natural light on visual comfort and productivity. The importance of these ideas in actual building environments is supported by the qualitative findings. The results of the study on the effects of daylighting on occupant psychological health are consistent with recent studies on the relationship between indoor settings and mental health. The subjective experiences of residents can be more fully understood using qualitative data.

V. CONCLUSIONS

This study, which explored the experience components of daylighting techniques using a qualitative research methodology, added to the body of quantitative research by exploring this topic in greater depth. It provided a comprehensive knowledge of the impact these techniques have on building inhabitants' wellbeing. The results highlight the careful balancing act necessary when developing daylighting systems to maximize occupant comfort and energy efficiency. This balance takes into account user control, behavioral adaptability, and architectural design. The study highlights the significance of an occupant-centric design strategy, in which user requirements, preferences, and behaviors are key to determining how buildings are designed.

A collaborative effort between architects, engineers, and lighting designers should be prioritized in an integrated design approach for construction projects. The comfort of the occupants is increased while ensuring that daylighting tactics are in line with energy saving objectives. Spaces that suit the requirements and preferences of building residents may be created by actively including them in the design process. The contentment and well-being of residents can be increased by giving them control over daylighting systems. The positioning of windows, light shelves, and shading mechanisms are all architectural design features that architects should pay close attention to. The impact of these characteristics on daylighting solutions' efficacy can be substantial.

The effective use of qualitative research techniques in this study emphasizes the importance of qualitative research for comprehending the experiential facets of architectural design. In studying building performance, it emphasizes how complimentary qualitative and quantitative techniques are. The study confirms the basic ideas of daylighting and shows their applicability to attaining energy savings and occupant comfort. It shows how these ideas are put into practice in building inhabitants' day-to-day experiences. This study emphasizes the significance of user-centric design methodologies and stresses that occupant demands, preferences, and behaviors should be key factors in the design process.

Future research may focus on the long-term impacts of daylighting on energy efficiency and occupant comfort. This calls for continuous observation of the functionality of the structure and tenant satisfaction. In light of the impact of climate and regional context on daylighting tactics, future study should look at climate-responsive design solutions that optimize advantages in various geographic areas. Research might examine the incorporation of intelligent daylighting systems that are flexible to changing environmental circumstances and human preferences as a result of technological improvements.

This study has, in the end, shed light on the complex link that exists between daylighting techniques, energy effectiveness, and occupant comfort in buildings. It has come to light that properly applied daylighting solutions have the ability to dramatically lower energy usage while also significantly improving the physical, psychological, and general well-being of building occupants. A deliberate and comprehensive strategy that takes into account architectural design, user interaction, and behavioral changes is necessary to achieve this balance, though.

The research's conclusions and findings highlight the significance of occupant-centric, holistic design strategies for developing environmentally friendly, pleasant, and energy-efficient built environments. This research is a significant resource for directing future practices and research initiatives in the field of architecture and environmental design as we continue to confront the difficulties of sustainability and occupant well-being in building design.

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