Potentials of Fibre Optic Daylighting Systems in Najran University College of Engineering Corridors

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Effective use of natural light in buildings significantly reduces energy consumption by minimizing the need for artificial lighting. This study investigates daylight wastage in Najran University's College of Engineering due to insufficient policy implementation and underutilization of daylight technology during the design phase, despite ample available daylight. Using a mixed-method approach, the study found that 42.6% strongly agreed, and 57.6% agreed that daylight is wasted, while 21% had no opinion on this matter. Regarding technology, 42.4% both strongly agreed and agreed, but 54.5% did not know about fiber optic daylight system (FODS) harvesting. Policy implementation is crucial, with 42.4% having no awareness of daylight legislation, and 45.5% not having used daylighting codes before. Interestingly, 48.5% agreed, and 36.4% strongly agreed with the significance of daylighting in LEED and MOSTADAM ratings in Saudi Arabia. Observations indicated that roof-mounted daylight collectors using fiber optics were most effective throughout the day, followed by walls, particularly on the northern and southern facades. Basements were the least favorable due to limited access to daylight. In conclusion, this study highlights the potential of fiber optics for daylight harvesting, whether in retrofitting or new building design, given the region's abundant daylight.

Keywords: Daylight Wastage; Fiber Optic; Daylight Harvesting; Policy; Codes; LEED and MOSTADAM Ratings.

1. Introduction

Daylighting is a meticulous method of harnessing natural light to illuminate interior spaces effectively [1]. It involves strategically placing windows, transparent materials, and reflective surfaces to optimize natural illumination during daylight hours. Natural daylight can be harnessed from the outdoors by gathering and channeling it through light-guiding media, allowing it to penetrate deep into the interior of a building. Various daylighting systems have been explored to utilize this natural light source for indoor illumination [2]. Natural daylight can be harnessed from the outdoors and directed through light-guiding media, allowing it to penetrate deep into the interior of a building [3]. Numerous daylighting systems have been developed to utilize this natural light source for indoor illumination [4, 5]. Notably, the fiber optic daylighting system, which relies on solar concentrators and fiber optic transmission, has garnered significant interest due to its ability to provide dependable indoor lighting solutions that are both versatile and highly efficient [6, 7].

The Fiber Optical Daylighting System (FODS), relying on solar concentrators and fiber optic transmission, has garnered considerable attention due to its ability to provide reliable and effective indoor daylighting solutions with wide-ranging applicability [8, 9]. During the Industrial Revolution, the first commercial structures, including factories, workshops, and offices, were developed [10]. Indoor work required the workspace to have adequate lighting. These structures had high ceilings and narrow floor designs to maximize daylight penetration. Light wells allowed daylight to enter where deep multi-storey constructions were necessary. However, the development of fluorescent lighting radically altered building architecture. Large deep plan structures may now be built since the building's exterior was reduced to a simple layer of defense against the surroundings of an artificially lit and air-conditioned room [10]. People in today's society spend the majority of their time in these structures. “Humans have moved from a modern, developed environment with relatively dim, limited-spectrum days and nights to a terrestrial setting with dark nights and bright, broad-spectrum days”. The impact on people's health and well-being is one outcome of this change that has not yet been completely realized.

Additionally, the operation of these structures necessitates a significant amount of power and, consequently, energy from fossil fuels, which ultimately contributes to the emission of greenhouse gases. It is now widely acknowledged that anthropogenic greenhouse gas emissions have a significant role in global. One of the tenets of green and sustainable architecture is to minimize the structure's overall energy use in order to maximize the use of natural light and lessen the reliance on electrical lighting, especially in deep-plan structures [11]. In addition to increasing the visual appeal of buildings, adopting daylighting as an illumination source also has positive effects on occupants' productivity and health. The parts that follow go into greater detail about the advantages of daylighting in structures, the issue with deep-plan buildings, and the many daylighting options that are available for these structures, as well as their uses [12].

Fiber optic cables serve as conduits for transporting sunlight from the lighting source to an illuminator or fixture, and these cables can be constructed from either glass or acrylic materials. Optical fibers are often preferred due to their superior qualities, such as enhanced reliability, resistance to discoloration, and superior light intensity retention compared to acrylic. It's worth highlighting those optical fibers experience only a minimal 1% light output loss per foot of light travel along the cable, while acrylic fibers tend to lose up to twice as much light per foot. Importantly, regardless of the fiber optic material used, it's essential to acknowledge that light output diminishes as the distance between the lighting box collector and the fixture increases. For instance, a 33-foot cable delivers approximately 64% of the initial light intensity, while a longer 65-foot cable only transmits around 40% of the original light intensity [13].

This phenomenon underscores the need for careful consideration of cable length to ensure optimal daylighting performance. In addition to the cited source, it's valuable to note that this characteristic of light attenuation in fiber optic cables has been a consistent finding in various studies related to daylighting systems [14]. These studies collectively underscore the importance of cable length and material choice in maintaining efficient daylight transmission.

Although previous studies [15] have shown energy savings achieved through atrium and corridor lighting improvements, and the potential of fiber optic lighting has been recognized [16], there remains unexplored potential for energy savings through retrofitting lighting controls in various areas across Najran University's campus. It's also important to address the limitations of fiber optic lighting. Saudi Arabia's population, estimated at around 36 million in 2022, contributes to increasing energy consumption and wastage. Depletion of non-renewable energy resources, notably petroleum, necessitates intelligent and conscientious energy use to preserve these valuable resources for future generations. Sustainability and efficient energy use are essential, given the economic significance of petroleum in the region [16].

To the best of our knowledge, currently no research explored the potential of fiber optic daylighting systems (Fibre Optics Daylighting System) in Najran University's College being it the hot arid climate of Saudi Arabia. Several studies confirmed the potential of FODS to provide occupants with proper lighting to support visual functions research in [13, 15, 17] uses the FODS to reduce building energy consumption associated with lighting appliances. Similar study uses transparent window to reduce lighting energy consumption by over 70%.

Unlike previous study that focuses on harnessing solar lighting with aid of through solar panel and transmits it via fiber optic connections to illuminate indoor spaces. Our study does not required solar panels and limited to the corridors of the College of Engineering at Najran University despite but can be extend to offer various design possibilities.

2. DAYLIGHTING, WELL-BEING, AND SUSTAINABILITY

2.1 Daylighting

The successful implementation of daylighting demands a holistic approach throughout the building design process, encompassing site planning, architectural design, interior design, and lighting design. The integration of natural light into building design offers a multitude of advantages, ranging from aesthetic enhancements to physiological and economic benefits. Notably, the positive impact of natural light on occupant health and performance is a pivotal consideration in contemporary building design [17]. Daylighting has the potential to elevate architecture in several significant ways. Incorporating these facets of daylighting into architectural design not only elevates the overall quality of built environments but also aligns with contemporary principles of sustainability and well-being. Daylighting offers numerous avenues through which it can significantly enhance architectural design.

One of its foremost contributions lies in its capacity to elevate the visual appeal of architectural spaces. Skillful integration of daylighting elements creates inviting and aesthetically pleasing environments. Beyond aesthetics, well-executed daylighting positively impacts the health and well-being of occupants. It caters to their psychological and visual comfort needs, fostering a healthier indoor atmosphere [18]. Human beings have an inherent need for exposure to natural daylight to fulfill their psychological and physiological comfort requirements. Daylighting satisfies this fundamental need. A compelling aspect of daylighting is its inherent eco-friendliness. Harnessing natural light comes at virtually no environmental cost, aligning with sustainability principles that benefit both occupants and the planet. A key objective of daylighting is to minimize reliance on artificial lighting sources [19]. This deliberate reduction in artificial lighting usage results in substantial electricity cost savings over time. Beyond lighting, effective daylighting can play a pivotal role in optimizing heating, ventilation, and air conditioning (HVAC) systems. Natural lighting generates minimal heat when judiciously controlled, contributing to improved HVAC efficiency.

Over a decade ago, the growing preference for daylight and heightened awareness of its positive impact on health led to increased interest in the development of fiber optical daylighting systems. Research efforts have been primarily concentrated on system design and technical advancements encompassing the collection, storage, transmission, and distribution of daylight. In a subtropical setting, one pioneering study introduced an innovative Cassegrain solar concentrator system that incorporated a chromatic lens to reduce the transmission of UV and IR components of daylight [20]. Another successful implementation involved an optical fiber solar concentrator, which proved its effectiveness in a tropical environment. This system comprised a PMMA (Polymethylmethacrylate) plate and 150 three-color fluorescent fibers [21].

2.2 Daylighting and Well-Being

Daylighting's impact on human health is a multifaceted concept encompassing crucial elements [10]. Among these elements, light intensity and ultraviolet (UV) light exposure play pivotal roles in shaping various aspects of well-being. Numerous studies have underscored the profound influence of bright light, be it from natural or artificial sources, on an array of health outcomes.

Adequate daylight exposure offers multiple health benefits, including the potential to alleviate symptoms of depression by improving mood and reducing depressive symptoms. Daylighting also contributes to reduced agitation, creating a more peaceful environment. Moreover, daylighting positively influences sleep patterns and circadian rhythms, as natural light plays a crucial role in regulating the body's internal clock [22]. Light signals wakefulness, while darkness signifies the need for rest. When one's internal clock is out of sync with the natural light-dark cycle, it can lead to issues like morning fatigue and evening alertness, disrupting the sleep-wake cycle.

Exposure to natural light, particularly during darker months, has been proven to alleviate symptoms of Seasonal Affective Disorder (SAD) and enhance overall mental well-being. Additionally, studies [23] have highlighted the positive impact of daylighting on occupants' mood and morale in various settings, from offices to industrial spaces and retail environments. Well-lit spaces are associated with increased employee morale, reduced fatigue, and decreased eye strain, contributing to higher job satisfaction and productivity. These findings underscore the significant influence of light quality on human health and performance in different built environments. Consequently, daylighting practices have become a fundamental aspect of modern architectural design, with architects, designers, and building professionals recognizing its role in promoting well-being and efficiency in indoor spaces, making it an essential consideration in building design and construction [24].

2.3 Daylighting-Sustainability

Recent research proposed an approach that control the quantity of sunlight and solar heat that enters the building using smart window systems. The regulating systems Smart windows include active and passive window glazing that adjusts to changes in temperature or sunshine as well as automatic shade management that regulates light levels throughout the day [25]. With further study now looking at its use in flexible substrates for better efficiencies at low cost and longer-lasting devices a technique employed in [26] displays a maximum efficiency of 22.3% manufactured in lightweight construction material products. A method employs cutting-edge thin-film technology in smart windows, which are akin to smart meters, to react to natural ventilation.

According to earlier modeling studies [27], a smart windows that uses daylighting practices can save a building's energy requirements by up to 40% when compared to static windows. Study in [28] indicates underlying functioning principles of smart windows can be divided into three primary categories. While photochromic and thermochromic windows respond to environmental stimuli by changing their transmittance with changes in light intensity and temperature, respectively, electrochromic windows change transmittance when applied voltages are applied [29]. Study in suggested a smart window that reversibly switches between a transparent state and a blocking state to dynamically manage the transmittance of solar radiation into buildings [30]. This is one of the newest and most promising technological solutions that can lower HVAC energy use in buildings while also reducing glare, obstructing views, and increasing natural daylighting [31].

The goal of FODS to ensure optimal energy saving on the basis of the daylighting data utilized as an input to manage indoor lighitng. The technology can be categorize into two groups in this context (see Table 1). Resposive approach or smart window and static approach. In the first category of control systems makes use of daylighting in collaboration with illuminance infrared sensor alonside control algorithms that take into account both ambient temperatures and individual energy usage patterns. However, most of the first-category solutions can not accurately capture the occupant experience on lighting level (brighter or dimmer) which leads to increase in energy use. While in second category, the technology uses machine learning to estimate the total occupant number and then modify the amount of light penetrating through window in line with the number of people present in the room.

Smart lighting literature most researched area in smart homes. Every day there is a growing need for smart lighting, particularly for impending rapid LED projects for smart buildings and cities. Several smart lighting solutions are available right now to demonstrate various fascinating gestures and emotions while emitting relevant colors. For instance, Philips Hue-

Hue Go and the Logitech POP smart button offer ambiance and elegant colors to the home while also lighting it up, calming the atmosphere and conserving energy [32].

The attributes of the device type affect how smart lighting works. To prevent lighting up empty space, all have infrared capabilities and brightness features [33]. The sophistication of modern smart lighting technology is now at an all-time high.

By turning off window when they are no longer needed, which significantly increase energy usage performance without requiring the user to be nearby or even at home. A portion of the current methods employ user behavior to determine how much energy is used [27, 28]; other studies in [8, 14, and 19] used external information, such as energy prices, to determine when to use daylighting [6].

The smart window can track a building's status and make decisions based on these updates to decide when to use energy from grid or natural lighting. However, very few studies take into account the window-opening patterns of occupant interior ventilation and energy efficiency. Findings reveal that smart windows use machine learning to build occupant profiles to achieve greater influence on energy savings.

3. Materials and Methods

3.1 The case study site

College of engineering Najran University, Saudi Arabia is a public institution of 18 km2 that has two main campuses and is gender-segregated. The university's extensive campus encompasses a diverse array of facilities, including administrative buildings, support deanships, a fully equipped university hospital, sports and entertainment venues, public school buildings, as well as residential accommodations for both faculty and students. The university's student body, which currently has about 12,204 students (7344 females and 4860 males), is rapidly expanding. There are 661 staff members (489 men, 172 women) and 1365 faculty members (900 men, 465 women). All of these individuals work full-time hours; classes for students and staff are typically held from 8:00 a.m. to 2:15 p.m., with rush hours occurring from 7:30 to 8:30 a.m. and from 1:30 to 3:00 p.m. There will be a significant increase in the number of university students, which will necessitate hiring more faculty and staff. As depicted in Figure 1 and 2; the campus features a total of eight gates, with active usage restricted to just two of them. The primary transportation infrastructure comprises two main ring roads encircling NU: one encircling the male campus, and the other dedicated to the female campus. According to the University Council's recommendation, the College of Engineering was founded in 1431 AH as one of the University's other 14 colleges to address the needs of the Najran Region. In its strategic plan, the college has established six scientific departments.

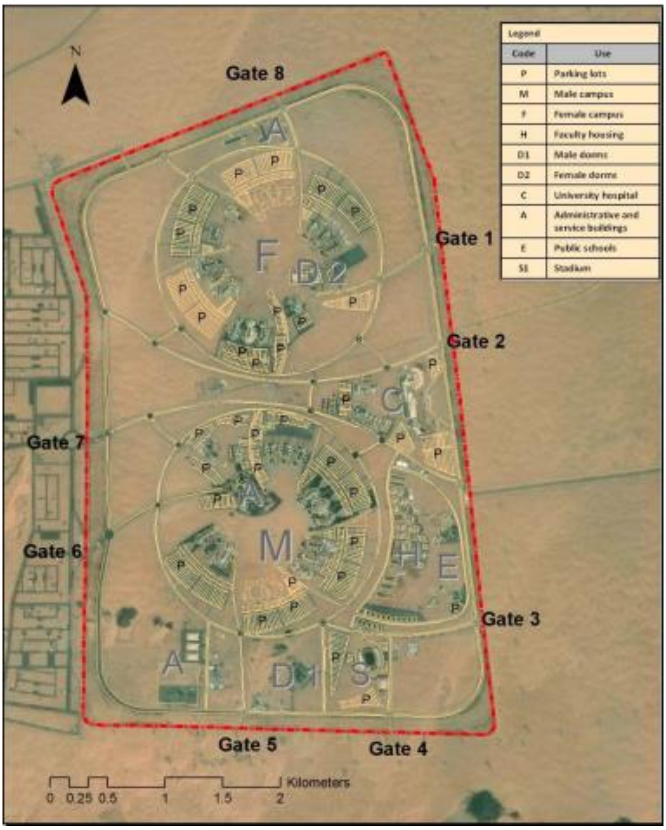

Figure 1. Aerial view of Najran University

Figure 2. Aerial view of the college of engineering, Najran University

A region is classified as having a hot-humid climate when it meets one or both of the following criteria and receives an annual precipitation of more than 20 inches (approximately 51 cm): Wet bulb temperatures of 67 °F (19.44 °C) or higher for a duration of 3,000 hours or more during the six hottest months of the year. Temperatures of 73 °F (around 23 °C) or higher for 1,500 hours or more during the same six hottest months in the Kingdom of Saudi Arabia as shown in Figure 3. In this climate, humidity levels are generally moderate, except for coastal areas where humidity can be uncomfortably high. Precipitation levels are consistently low across the region, with Jeddah receiving an approximate 2.5 inches (about 6.35 cm) of annual rainfall, Riyadh receiving just over 3 inches (approximately 8 cm), and Al-Dammam receiving around 3 inches of precipitation annually [15].

Month	Jan	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct	Nov.	Dec.
Sun Hours	230	260	315	372	386	375	374	372	346	301	225	231
Global Horizontal Irradiance Wh/m2	229	268	285	294	317	322	295	300	294	285	246	222
Cloud cover %	1	16	10	5	3	2	17	15	1	0	2	1
CIE Overcast range %						≥80						

Figure 3. Average monthly sunlight hours, global horizontal irradiance, and cloud cover of najran city [15].

Najran is situated in the southwest region of Saudi Arabia, with geographical coordinates of approximately 17°29′30″ N latitude and 44°7′56″ E longitude. The city experiences a desert climate, characterized by temperature variations between approximately 17 °C in the winter and 45 °C in the summer. Saudi Arabia ranks as the second sunniest country globally, and Najran is among the cities with some of the highest daily solar radiation levels, exceeding 6.9 kWh/m2/day. Najran City enjoys more than 3600 hours of sunlight annually, translating to an average of 10 sunny hours per day throughout the year. The monthly distribution of sunshine hours ranges from 357 hours from April to August to 260 hours in the remaining months. Figure 4, 5 and 6, presents the corridors of college of Engineering, Najran University; main entrance of college of Engineering, Najran University; and the corridor of the college of Engineering, NU. Najran City typically maintains low cloud cover, with an average peak of less than 20%, as per the CIE (International Commission on Illumination) standard. A clear sky is defined as having less than 30% cloud coverage, while a cloud-covered sky exceeds 70% cloud coverage. Consequently, Najran City enjoys consistently clear skies throughout the year[15]. On a clear day, direct sunlight can produce luminance levels of up to 100,000 lux at midday, providing abundant daylight. The city's climate remains consistently sunny, making it challenging for researchers to assess daylight factors associated with adverse sky conditions like overcast skies. As a result, this study focuses on measuring and analysing daylight illuminance in Najran City under clear sky conditions [15].

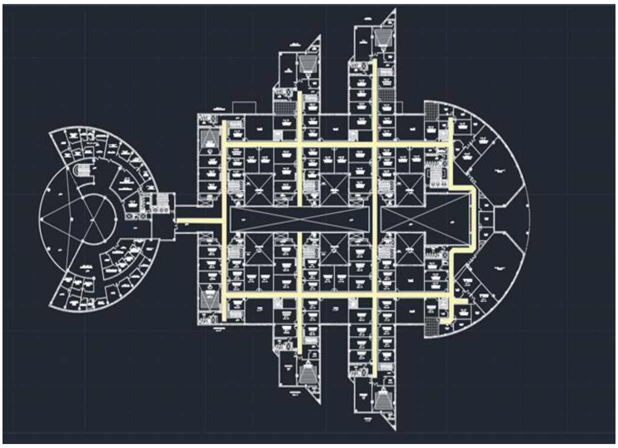

Figure 4. The corridors of college of engineering, Najran University

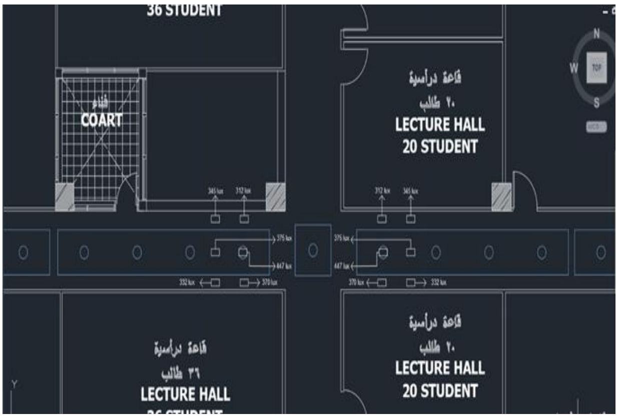

Figure 5. Main entrance of college of engineering, Najran University

Figure 6. Photo of part of the corridor to be examined college of engineering, Najran University.

3.2 Quantitative measurement

Currently research confirmed that a mixed method research design produce more reliable outcome and therefore, this study employs a mixed methods approach, combining quantitative (questionnaire) and experimental methods [25]. This approach is known to comprehensively address research problems, producing more robust findings. Mixed methods research is ideal when a study involves variables with both qualitative and quantitative characteristics to address the research question comprehensively. This approach enhances the validity of findings by utilizing various research techniques. By incorporating both quantitative and qualitative methods, this study aims to provide a more complete understanding of the research question [26]. The choice of mixed methods enhances the depth and validity of the study's findings.

A comprehensive survey was conducted within the faculty, encompassing various data collection methods. This survey involved on-site observations of corridors to assess the potential for utilizing daylight as a lighting source. Additionally, it entailed an examination of the existing fluorescent and lighting systems in place. Furthermore, a questionnaire, adapted from established studies, was meticulously prepared and administered to gauge its reliability.

The questionnaire served as a means to gather insights from respondents by posing a series of pertinent questions. For this final project, individuals employed within the engineering college were surveyed on several key aspects. These inquiries revolved around whether the institution employed any technology systems for harnessing daylight and sought opinions on the expenditure associated with artificial lighting.

To ensure the questionnaire's reliability, the Cronbach's alpha test was initially conducted, yielding a score of 0.559. Subsequently, refinements were made to the questionnaire, resulting in an improved score of 0.734, which was deemed satisfactory. Following this validation process, the revised questionnaires were distributed to all employees within the engineering department. It's worth noting that the questionnaire's initial design was tailored to the department of architecture but was subsequently adapted to suit the needs of all engineering departments. The questionnaire encompassed a range of questions, including demographic inquiries and queries pertaining to respondent awareness of daylight harvesting and available technologies. These questions were drawn from a variety of established and validated research sources.

Assessing the reliability and validity of the questionnaire is a crucial step in the research process. To ensure its accuracy and effectiveness, the questionnaire was administered to a group of five individuals. Subsequently, the Alpha Cronbach test was employed to evaluate its reliability, yielding an initial result of 0.5. In response to this initial assessment, necessary refinements were made to enhance the clarity and overall quality of the questions. These modifications led to a significantly improved Cronbach's alpha score of 0.686. The finalized set of questions, following these improvements, is provided above for reference.

Observation is a versatile method in research, offering a dynamic framework with permutations tailored to the researcher's objectives, research type, and data conditions. This study adopted an observational framework [27, 28]. Additionally, photographic evidence was collected to supplement the observations because photographs convey experiences beyond verbal descriptions [29].

Direct observation was chosen as the primary data gathering method due to its effectiveness in capturing accurate information. This approach involves the researcher visiting the site, employing a checklist, and recording observations as they occur. While participant observation is often associated with ethnography, it can be applied to construction research, given the need for immersive, real-time data collection. In this study, the nature of construction operations justified a shorter fieldwork period compared to ethnography. Observations can be overt or covert. Overt observation, where participants are aware of being observed, presents challenges of potential bias and staged behavior. Covert observation, though ethically demanding, avoids these challenges. The importance of selecting the most reliable, suitable, and ethically sound approach makes the covert approach the preferred choice in this study to ensure data validity [25].

A range of observational techniques, such as process descriptions, dialogues, and activities, were used to meet research goals. The observation process was structured into three visits, each separated by a week. The preliminary visit included an interview with site supervisors to understand waste disposal practices and management strategies. During this visit, sketches were also made. The main visit involved extended observation at discreet spots on the site, rotated to cover different areas. Observations coincided with site activity times, i.e., 09:00, 12:00 noon, and 04:00 pm, for a week (Sunday, Wednesday, and Friday). Data collection utilized an observation checklist.

3.3 Experiment

In this experiment, a scaled-down model of a building section, depicted in Figure 9, will be employed. Daylight plays a fundamental role in architectural projects, and architects have utilized scale models since ancient times to evaluate their designs in real-world conditions. Despite advancements in computer simulations that offer rapid and precise results, architects still find value in personally experiencing a space's lighting and qualitatively comparing design options. Computer simulations may not fully replicate the intuitive understanding provided by scale models at present.

Scale models faithfully represent how daylight is distributed within the model, mirroring real-world conditions. Studies on daylighting conducted under sky and sun simulators have demonstrated highly accurate results when compared with straightforward models. This hands-on approach remains essential in architectural evaluation, allowing architects to gain a comprehensive understanding of lighting nuances that computer simulations may not capture with the same depth.

Experimental scale models serve as small-scale representations of larger objects or structures, allowing researchers to conduct experiments to assess their functionality, safety, and effectiveness before constructing full-sized versions. These models provide a clear and practical means of obtaining real-world results for research purposes. In the context of this experiment, the key components include fiber optics, which are highly critical as they respond to daylight transfer.

FULL DIY TUTORIAL Sunlight collector using optical fibers	https://www.youtube.com/watch?v=DN8GXTmR6RI		
Fresnel lens 20mm			Yes
Fiber Optic Cable	https://www.amazon.sa/-/en/CHINLY-0-03in-0-75mm-Plastic-Ceiling/dp/B01N0QCAHF/ref=pd_lpo_2?pd_rd_w=ChR4i&content-id=amzn1.sym.11e95c61-d790-42f4-9b6f-d73dda176294&pf_rd_p=11e95c61-d790-42f4-9b6f-d73dda176294&pf_rd_r=SACK9QNHN054WEQX7CC9&pd_rd_wg=XIld2&pd_rd_r=f70c16f3-35b7-4a44-bb41-eca9f7b63ade&pd_rd_i=B01N0QCAHF&th=1		yes
Upgraded Led Lens with 20mm Diameter Black Holder For Led Light 13mm Height	https://www.fruugosaudiarabia.com/upgraded-led-lens-with-20mm-diamter-black-holder-for-led-light-13mm-height/p-77076009-155740822?language=en&ac=google&asc=pmax&gclid=CjwKCAiAqt-dBhBcEiwATw-ggNXStrRKkZ6KsBVuULjE6Wm7e-SUz4HlUA1sGeQNqxddlh376_FYGxoCSXgQAvD_BwE		NO 5 pieces
3W Spotlight Kit Plano Convex Led Lens with Holder	https://www.alibaba.com/pla/3W-Spotlight-Kit-Plano-Convex-Led_1600424745963.html?mark=google_shopping&biz=pla&searchText=led+lenses+reflectors&product_id=1600424745963&pcy=US		NO 5 pieces

Figure 7. List of items used for the scale model experiment

Notably, the length of fiber optics does not affect the amount of daylight they can capture, and they can function effectively in both horizontal and vertical orientations. When correctly installed and protected from environmental elements, fiber optic cables can have a lifespan of several decades. The second component is the fiber collector, which, while it is established that fiber optics can obtain light without a collector, is used in this experiment. Lenses were employed as collectors in our study to facilitate the collection of light. Figure 10 provides a comprehensive list of items used in the scale model experiment.

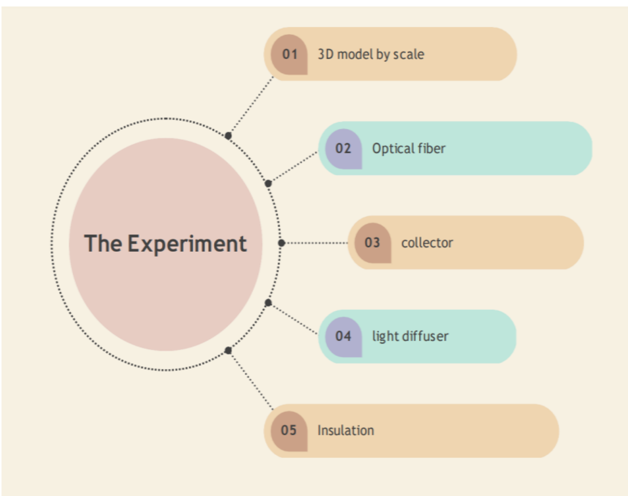

Figure 8. List of items in the experimental process

As commonly understood, a lens is a meticulously crafted or molded transparent material that utilizes refraction to manipulate light rays and produce an image. When light encounters a lens, it undergoes refraction at each of its boundaries. Upon entering the lens, the light beam is refracted, and it undergoes refraction as it exits the lens. This dual refraction causes a change in the direction of the light beam. The specific geometric shape of the lens is instrumental in refracting the light beams to produce focused and directional illumination.

4. Results and Discussion

4.1. Quantitative results

The results of the quantitative analysis were presented in Table 1 and Table 2. The majority of respondents express agreement regarding daylight wastage, with 42.6% strongly agreeing and 57.6% simply agreeing, while 21% lack a clear understanding of daylight wastage. In terms of technology, 42.4% both strongly agree and agree, while 54.5% are unfamiliar with the use of fiber optics for daylight harvesting. Policy emerges as a crucial factor, as its presence facilitates the assimilation of awareness and technology; however, 42.4% of respondents lack knowledge about daylight legislation, and 45.5% have not used daylighting codes before. Notably, 48.5% express agreement, and 36.4% strongly agree with the significance of daylighting LEED and MOSTADAM ratings in Saudi Arabia.

The survey results provide valuable insights into the perspectives and awareness levels of the respondents regarding daylighting and related factors. In terms of the daylight wastage; a significant proportion of respondents acknowledge the issue of daylight wastage. Specifically, 42.6% of the respondents strongly agree, indicating a high level of concern, while an additional 57.6% simply agree. This combined response suggests that a majority of the respondents believe that daylight is not being utilized efficiently. However, it's worth noting that 21% of the respondents appear to lack a clear understanding of the concept of daylight wastage. This corroborates the concept of daylight wastage and its significance in building design has been explored in research that centered on daylight performance of educational buildings in hot arid regions. This past study delves into the awareness and potential mitigation strategies for daylight wastage.

This subset of respondents may require further education or information on this topic. The results relating to technology and fiber optics inform that when it comes to technology, 42.4% of the respondents both strongly agree and agree with its importance. This indicates that a substantial portion of the participants recognizes the significance of technology in the context of daylighting. Surprisingly, 54.5% of the respondents admit that they are unfamiliar with the use of fiber optics for daylight harvesting. This finding suggests that there is a notable gap in awareness regarding this specific technology among the surveyed individuals. This buttressed by past studies31; on the importance of technology in daylighting has been a subject of interest in several studies. This research highlighted the role of technology, including computational tools, in optimizing daylighting strategies; through the utilization of fiber optics in daylight harvesting. The study supports insights into optical daylighting systems, including the use of fiber optics, for achieving healthy indoor environments.

For policy and legislation; policy emerges as a crucial factor in the effective implementation of daylighting practices. It is observed that having a policy in place can facilitate the assimilation of awareness and technology. However, 42.4% of the respondents do not have knowledge about daylight legislation, indicating a potential need for greater transparency and communication about related policies. Additionally, 45.5% of the respondents have not used daylighting codes before. This may indicate a lack of familiarity with existing regulations or guidelines governing daylighting practices.

In the realm of policy and legislation, it is imperative to recognize its pivotal role in shaping and promoting effective daylighting practices within building design and construction. Numerous studies have highlighted the significance of policy frameworks in driving the adoption of sustainable building practices, including daylighting. A similar in their study 'Assessing the Impact of Building Energy Codes on Energy Performance and Carbon Emissions in Commercial Buildings' underscores the critical role of building codes and regulations in enhancing energy efficiency, which encompasses daylighting strategies. This research showcases how well-designed policies can serve as catalysts for the integration of energy-efficient technologies, including daylight harvesting systems.

However, our survey reveals a concerning gap in awareness regarding daylight legislation among the respondents. Specifically, 42.4% of the participants admitted to lacking knowledge about daylight legislation see (Table 1). This finding echoes the sentiment expressed in studies where it is emphasized that effective policy dissemination and communication are essential to ensure stakeholders are well-informed and compliant with regulations. Furthermore, our results indicate that 45.5% of the surveyed individuals have not used daylighting codes before. Their study highlights the need for better education and enforcement mechanisms to ensure that building professionals are well-versed in and adhere to daylighting codes.

The survey also delved into respondents' perspectives on the significance of daylighting within the context of LEED and MOSTDAM ratings in Saudi Arabia. Research in the field of sustainable building practices has consistently highlighted the importance of these ratings in driving sustainable design and construction. These ratings provide benchmarks and incentives for incorporating sustainable features, including daylighting, into building projects.

The survey results corroborate these findings, with 48.5% of respondents expressing agreement and an additional 36.4% strongly agreeing with the significance of LEED and MOSTADAM ratings. These statistics underscore the recognition of these ratings as influential factors in sustainable building practices in Saudi Arabia. Summarily, the survey outcomes reveal varying levels of awareness and agreement among the respondents regarding daylighting, technology, policy, and sustainability ratings. These insights align with the recommendations of similar studies in 'Exploring the Factors Influencing Green Building Implementation in Malaysia' and in 'Barriers to implementing sustainable residential building in Ghana: Perspective of Ghanaian building professionals,' which highlight the importance of tailored educational initiatives, policy advocacy, and technology promotion to foster the adoption of efficient daylighting practices in the surveyed region.

Table 1. Result from questionnaires administer highlighting findings in percentage

1	Demography	39.4%	27.3%	24.2%	9.1%
2		Architecture Students	Related to Architecture	Not Related to Architect	Non Architecture Students
3	Awareness	Q1	Q2	Q3	Q4
	Stg. Agreed	42.6%	39.4.%	33.3%	27.3%
	Agreed	57.6%	36.4%	45.5%	36.4%
	No Idea	-	18.2%	21.2%	27.3%
	Disagreed	-	3%	-	9.1%
	Stg. Disagreed	-	3%	-	-
4	Technology	Q1	Q2	Q3	-
	Stg. Agreed	42.4%	12.1%	21.2%	-
	Agreed	42.4%	18.2%	60.6%	-
	No Idea	15.2%	54.5%	15.2%	-
	Disagreed	-	12.1%	3%	-
	Stg. Disagreed	-	3.1%	-	-
5	Policies	Q1	Q2	Q3	Q4
	Stg. Agreed	9.1%	6.05%	36.4%	-
	Agreed	33.3%	30.3%	48.5%	-
	No Idea	42.4%	45.5%	15.2%	-
	Disagreed	12.1%	12.1%	-	-
	Stg. Disagreed	3.1%	6.05%	-	-

4.2 Results on experiment [scaled model]

The measurements were taken using a Fresnel lens without focusing, resulting in a range of approximately 55 lux to 110 lux. However, when the measurement was concentrated on the fiber optics, a much higher level of illumination was achieved, ranging from 1000 lux to 1300 lux. These measurements were conducted at a horizontal plane in tandem with a study [33]. Additionally, when the measurement was taken while facing the solar radiation source, an even higher external luminance of up to 63,000 lux was recorded.

The results in Table 2 present the results of the experiment, indicating that when using a Fresnel lens without focusing, the illumination levels are relatively low, ranging from 55 lux to 110 lux. However, when the measurement is concentrated on the fiber optics, there is a significant increase in illumination levels, ranging from 1000 lux to 1300 lux. This is in line with a previous study (Ullah, et. al., 2017), that affirmed the effectiveness of fiber optics in harvesting daylight and increasing illumination levels. This infers that when facing the solar radiation source, the external luminance reaches an exceptionally high level of up to 63,000 lux, highlighting the potential for utilizing natural sunlight as a significant light source. This observation aligns with previous research findings that emphasize the remarkable illuminance levels attainable through daylighting systems.

Several studies have underscored the substantial luminance achievable when harnessing natural sunlight for indoor illumination. For instance, a research conducted comprehensive review of fiber-optic-based daylight enhancement systems in buildings documented instances where such systems effectively harnessed sunlight to provide ample luminance levels within interior spaces. They highlighted the capacity of fiber optic systems to capture and transport sunlight, leading to improved indoor illumination, which is in line with the exceptionally high luminance mentioned.

Table 2. Result from daylighting experiment carried out using fibre optics

<table>
<tr><td colspan="4">Operating variables</td><td colspan="2">Response variables</td></tr>
<tr><td colspan="4">Solar Intensity W/m²</td><td colspan="2"></td></tr>
<tr><td colspan="2">Fresnel Lens</td><td colspan="2">Water</td><td>Lux</td><td>Photo of inside of the model</td></tr>
<tr><td>Free</td><td>Concentrated</td><td></td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>55</td><td>1,003</td><td></td><td></td><td></td></tr>
<tr><td>110</td><td>1,290</td><td colspan="3"></td></tr>
<tr><td colspan="2">Fresnel Lens at horizontal position</td><td>57,000</td><td>63,000</td><td>70,000</td><td>63,000</td></tr>
<tr><td colspan="2">Fresnel Lens facing Solar Radiation</td><td>110,00</td><td>87,000</td><td>92,000</td><td>96,000</td></tr>
</table>

Similarly on a daylighting system based on a novel design of linear Fresnel lenses demonstrated the potential for achieving significant external luminance levels. Their innovative design allowed for the efficient concentration and distribution of sunlight, contributing to the elevated illuminance within buildings. Moreover, studies [34, 35] explored designs for uniformly illuminated spaces using Fresnel lens-based optical fiber daylighting systems. These investigations emphasized the importance of achieving consistent and high luminance levels through sunlight utilization, further corroborating the notion of abundant external luminance.

In similar research [36] on the development of a fiber solar concentrator for indoor illumination demonstrated the potential for daylighting systems to generate substantial luminance, thus reducing the reliance on artificial lighting. Collectively, these past studies support the notion that harnessing natural sunlight can yield exceptionally high luminance levels, highlighting the substantial potential for daylighting systems to serve as a significant and energy-efficient light source within buildings.

5. Conclusion and Recommendation

The study conducted a thorough investigation into the issue of daylight wastage within the College of Engineering at Najran University. The primary concern identified was the lack of policy implementation and utilization of daylight harvesting technology during the design phase, despite the abundant availability of daylight in the region. To assess the feasibility of harnessing daylight efficiently, a scaled model experiment was meticulously carried out, with a specific focus on the potential use of fiber optics for daylight harvesting. The research findings revealed several crucial insights. In conclusion, while policy plays a pivotal role in the successful implementation of daylighting practices, our survey results suggest a need for enhanced transparency, education, and communication regarding daylight legislation and codes to bridge the knowledge gap and promote effective daylighting strategies in building design and construction.

The study underscored the significant potential for conserving energy through daylight applications. However, it was evident that there was a notable absence of technological approaches to harness the substantial daylight resources available within the college. The research also sheds light on the importance of implementing daylighting codes. It was evident that existing daylighting codes, particularly to MOSTADAM and LEED rating systems, were not rigorously enforced within the kingdom. This gap highlighted the need for stricter adherence to such codes to promote sustainable building practices. The concluded the significance of sustainable building ratings and the need for targeted efforts to enhance awareness and adoption of efficient daylighting practices in Saudi Arabia, aligning with the broader global trend towards sustainable building and design."

6. Research Implication

The present study offers valuable insight into the existing body of literature on the subject of daylighting. It can benefit not only the concerned academic and research community, and developers/manufacturers of building technologies, but also the broader building industry stakeholders on multiple fronts. Firstly, this study provides a comprehensive review of the literature covering various daylighting approaches in building technologies in terms of their functions and applications. Secondly, the study presents a finding that identify the gaps in the literature especially covering multiple dimensions of building. The finding of our study indicates major trends as well as issues with existing building daylighting strategies and technologies. More research may enhance this aspect by offering useful information for selecting the best strategies, technologies or algorithms to assist those tasked with selecting or designing realistic daylighting control solutions. The research could be expanded in both longitudinal and comparative contexts.

6.1 Practical Implications

The study unequivocally stated that a considerable amount of daylight goes to waste within the university premises, which could otherwise be effectively harnessed for energy conservation. The proposed solution involved retrofitting the college with daylight harvesting technology. This approach not only promised to reduce energy consumption for lighting but also had the potential to decrease carbon dioxide emissions and enhance overall sustainability. Strategic Importance of Daylight Strategies: Furthermore, the research emphasized the increasing recognition of daylight strategies as a strategic solution for achieving energy efficiency in building design. Additionally, the positive impact of daylight on occupants' mood and health within office spaces was highlighted. This aspect was particularly relevant as it presented an opportunity for the university to save a substantial amount of money that was previously wasted on artificial lighting.

6.2 Theoretical Implication

The study's outcomes resonated with the principles of the Brundtland Sustainability theory, which advocates responsible resource usage to ensure a sustainable future for both current and future generations. The research underscored the importance of avoiding extravagance with resources and implementing efficient practices in building design and operation. In summary, this study not only identified the issue of daylight wastage but also provided a foundation for further exploration of fiber optics' applications in daylight harvesting, whether in new building designs or retrofitted structures. It advocated for the adoption of policies, codes, and technologies that promote sustainable energy practices, emphasizing the potential benefits for the university, the environment, and future generations.

This study recommends that the government should provide a legal framework to approve techniques that are considered compatible with modern-day industrial best practices. Pursue more proactive policies and measures in the future to hasten the process of developing obligation and right for daylight legislation plan, which is fundamental to creating a sustainable future. This study is limited the population sampling which was limited to purposeful sampling as the time will not permit for other viable sampling techniques. More studies on the variables that provide a better understanding of the dynamic of how fiber optics can be used to harvest daylighting in buildings could be studied in the future.

7. Research Limitation

This study is limited to certain factor as highlighted below:

a. The duration of the project time is too short to cover a detailed study

b. The semester that the study fall in the winter time

c. The population sampling was limited to purposeful sampling as the time will not permit for other viable sampling techniques

d. Ordering of gadget and equipment from abroad causes delay in carrying out the experiment on time

With the aforementioned limitation of the study which is as a result of 3 main criteria; 1) awareness on the available technology, 2) application of the same technology and technical know-how and 3) policies to implement this idea. This study is promoting that the Saudi Arabia government should provide a legal framework to approve and techniques that are considered compatible with modern-day industrial best practices. Pursue more proactive policies and measures in the future to hasten the process of developing obligation and right for daylight legislation plan, which is fundamental to creating a sustainable future. This could be utilized in environmental policy, likewise for sustainable urban planning.

8. AREA FOR FURTHER STUDIES

More studies on the following are recommendations for research in the future:

1. An extensive time should be allocated to the observation and experiment

2. More variables that provide a better understanding of the dynamic of how fiber optics can be used to harvest daylighting in buildings

3. Other methods like the use of [computer simulation] should be employed to help in validating the findings in the study.

4. Possible study on how to transfer light from one region to the other using fiber optics

5. Lifespan of the fiber and possible storage system as daylight only last between morning till sunset

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