Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 13, Issue, 02, pp.16058-16066, February, 2021

DOI: https://doi.org/10.24941/ijcr.40566.02.2021

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

DAYLIGHTING: AN ANALYSIS OF THE DEFINITIONS, THE STRATEGY IMPLEMENTED AND TOOLS THROUGH A SYSTEMATIC REVIEW OF THE LITERATURE

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ARTICLE INFO

Article History:
Received 27th November, 2020
Received in revised form
19th December, 2020
Accepted 17th January, 2021
Published online 26th February, 2021

Key Words:
Daylight,
Tools, Literature,
Output Analysis.

ABSTRACT

This is a study done on the research done by various authors worldwide on the effect of the daylighting on houses commercial building, library and some specific models and understanding through rationalising the outputs from the research. This paper summarises the studies conducted by various researchers from a 2018-2020 and their tools to determine the outputs and analysis of the output either software tools or mathematical analysis.

Citation: ***Alpana Kamble.*** **2021.** "Daylighting: An analysis of the definitions, the strategy implemented and tools through a systematic review of the literature", *International Journal of Current Research*, 13, (01), 16058-16066.

INTRODUCTION

Daylighting is the controlled admission of natural light, direct sunlight, and diffused-skylight into a building to reduce electric lighting and save energy. By providing a direct link to the dynamic and perpetually evolving outdoor illumination patterns, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs.
A daylighting system is comprised not just of daylight apertures, such as skylights and windows, coupled with a daylight-responsive lighting control system. When there is adequate ambient lighting provided from daylight alone, this system can reduce electric lighting power. Further, the fenestration, or location of windows in a building, must be designed in such a way as to avoid the admittance of direct sun on task surfaces or into occupants' eyes. Alternatively, suitable glare remediation devices such as blinds or shades must be made available.

Implementing daylighting on a project goes beyond merely listing the components to be gathered and installed. Daylighting requires an integrated design approach because it can involve decisions about the building form, siting, climate, building components (such as windows and skylights), lighting controls, and lighting design criteria.

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The science of daylighting design is not just how to provide enough daylight to an occupied space but also to do so without any undesirable side effects. Beyond adding windows or skylights to space, it involves carefully balancing heat gain and loss, glare control, and variations in daylight availability. For example, successful daylighting designs will carefully consider shading devices to reduce glare and excess contrast in the workspace. Additionally, window size and spacing, glass selection, the reflectance of interior finishes, and the location of any interior partitions must all evaluated.
A daylighting system consists of systems, technologies, and architecture. All of these components of every daylighting system or design, one or more of the following are typically present:

- Daylight-optimized building footprint
- Climate-responsive window-to-wall area ratio
- High-performance glazing
- Daylighting-optimised fenestration design
- Skylights (passive or active)
- Tubular daylight devices
- Daylight redirection devices
- Solar shading devices
- Daylight-responsive electric lighting controls
- Daylight-optimised interior design (such as furniture design, space planning, and room surface finishes).

Since daylighting components usually are integrated with the original building design, it may not be possible to consider them for a retrofit project. If possible, the building footprint requires optimised daylighting. It is only possible for new construction projects and does not apply to retrofits. With the building appropriately sited, the next consideration is to develop a climate-responsive window-to-wall area ratio. As even high-performance glazings do not have insulation ratings close to wall constructions, the window area needs to balance daylight admission and thermal issues such as wintertime heat loss and summertime heat gain. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) offers guidance on these ratios per climate zone in their Standard 90.1 energy code. However, these are primarily minimal for thermal performance and do not consider the admission of daylight.

A high-performance glazing system will generally admit more light and less heat than a typical window, allowing for daylighting without negatively impacting the summer's building cooling load. It achieved through spectrally-selective films. A low-emissivity coating is often part of these high-performance glazing units, further improving the unit's R-value. Design of Windows design to control the solar gains and potential glare stemming from a daylighting design. To this end, solar shading devices are often employed-particularly on the view windows-to minimise the amount of direct sun that enters the space. These are typically called overhangs. In addition to the considerations above windows, a daylighting-optimised fenestration design will increase system performance. The window has two essential functions in a daylit building:

- Daylight delivery or admittance,
- Provision of view to the occupants.

The former dictates glazing with a very high visible light transmittance (commonly abbreviated as VLT, or Tvis), the latter should have a relatively low Tvis to prevent glare. As a general rule, the higher the window head height, the deeper into space the daylight can penetrate. Therefore, good daylighting fenestration practice dictates that the window should ideally be composed of two discrete components: a daylight window and a view window. Many daylighting designs employ skylights for toplighting.While skylights can be either passive or active, most skylights are passive because they have a transparent or diffusing medium (usually acrylic) that simply allows daylight to penetrate an opening in the roof. They consist of a double layer of material, for increased insulation. By contrast, active skylights have a mirror system within the skylight that tracks the sun and increases the skylight's performance by channelling the sunlight down into the skylight well. Some of these systems also attempt to reduce the daylight ingress in the summer months, balancing daylighting with cooling loads.

Tubular daylight devices are another type of toplighting device. These devices employ a highly reflective film on a tube's interior to channel light from a lens at the roof, to a ceiling plane lens. Tubular daylight devices tend to be much smaller than a typical skylight, yet still, deliver sufficient daylight to dim the electric lighting. Daylight redirection devices take incoming direct beam sunlight and generally redirect it onto the ceiling of a space. These devices serve two functions: glare control, where the direct sunlight does not hurt the eyes of occupants, and daylight penetration, where sunlight is distributed deeper into a space that would not be allowed otherwise. Daylight redirection devices generally take one of two forms: a large horizontal element or louvred systems. Horizontal daylight redirection devices are often called light shelves. Daylight-responsive electric lighting controls are essential to any daylighting system. No daylighting design will save any energy unless the electric lights are dimmed or turned off when there is sufficient illumination from daylight. If daylighting features such as windows and skylights are considered together with daylighting functionality such as daylight-responsive dimming controls, then the daylighting-enhanced building will more than likely use more energy, not less, than a comparable building without any daylighting features. Daylight-responsive lighting controls consist of continuous dimming- or stepped-ballasts in the light fixtures. One or more photocells to sense the available light and dim or turn off the electric lighting in response.

An often-overlooked element in a successful daylighting design is the interior design. A daylight-optimised interior design considers furniture design, placement, and room surface finish for daylight performance. For example, office cubicle partition to have reduced heights, especially those running parallel to the south facade, enclosed offices will have spaces kept to a minimum, and walls and ceilings will be as highly reflective as possible and distribute the redirected daylight. By positioning work surfaces at a distance from the south facade, solar control is more manageable with smaller solar shading devices than if a desk or office is placed directly against the south facade. This concept is illustrated in the following figure and shows how a relatively small overhang provides full direct seasonal solar protection to the workspace. The area immediately adjacent to the south facade is circulation space.

LITERATURE REVIEW

Research Work Energy-Saving Potential of Daylighting in the Atria of Colleges in Najran University, Saudi ArabiaAbdultawab (Qahtan, Abdultawab MohammedEbrahim, Diaeldin A Ahmed, Hussein M, 2019). From the various studies conducted, Daylighting defined as the introduction of natural light to the interior. An atrium is typically a large and multi-storeyed, glass-roofed space to introduce daylight to the interiors of large buildings where sidelight alone cannot penetrate the spaces (Mark & G. Z., 2014). However, in a hot and dry climate, the atrium or enclosed courtyard brings natural light indoors. It keeps them indoors relatively comfortable as it is self-shading most of the day and protected from hot winds (Lechner, 2015).

Moreover, the atrium increases the total area exposed to daylight by providing a large opening in the building core and energy savings (Stanley K.H. Chow, 2013). The amount of this daylighting available on the atrium floor depends on several factors: the translucency of the atrium roof, the reflectance of the atrium walls, and space (depth versus width) (Lechner, 2015). The atrium floors recommended illumination level recorded in some studies as 100 lux and IES standard as a maintained horizontal illumination of 200 lux (Hourani & Hammad, 2012). This research on the energy-saving potential recognised as an effective strategy for enhancing visual comfort and reducing energy used for electric lighting. Najran University, Saudi Arabia, has 15 colleges for males and ten colleges for females.

Each college has several atria and courtyards for introducing daylighting into the hearts of college buildings. However, the electrical lights used in the college's atria and linked corridors keep on all the daytime. This study attempted to investigate the daylight illuminance level and energy-saving potential on the atria and linked corridors when it incorporates a time-scheduling lighting control system—the field measurements conducted in the College of Applied Medical Sciences. The results indicate that daylight illuminance in the atrium spaces is abundant with an average illumination level on the atrium floor varying from 300 lux to 3 600 lux, depending on the day's time. In the clear sky climate of Najran city throughout the year, the time-scheduling control system is effective. It contributes to approximately 43 855.2 kWh of annual energy savings in electrical-lighting consumption in the present case study scenario. The total annual energy savings from all 25 colleges at Najran University is 1 096 380 kWh/year, which results in a cost-saving of approximately 93,512.86 USD. There would be substantial additional savings from other atria and courtyards in all of the college buildings throughout the campus.

The methodology adopted by this study was a case study to investigate the daylight illuminance level in atria and linked corridors in the College of Applied Medical Sciences at Najran University, under the hot arid climate of Najran City. A daylight illuminance of a selected atrium measured on different days of the year. Lighting fittings monitored, and calculation conducted to report the energy saving from a daylight harvesting. The daylighting of the atrium space monitored at different times of the year, on January 2018 (different times of the day) to represent wintertime with a minimum global horizontal irradiance of 229 Wh/m2, and June 2018 at midday to represent summer and days with the highest value of global horizontal irradiance of 322 Wh/m2.

This research combines daylight and energy assessment for the atrium and surrounding corridors in education buildings in a hot arid climate. Najran City has a clear sky throughout the year with abundant daylight to meet the demand for lighting a building during working hours. This study recommends building owners and designers to integrate electrical lighting-daylighting by intelligent lighting control, particularly time-scheduling control, for further energy saving in buildings. Research on Multi-objective optimisation framework for designing office windows: quality of view, daylight and energy efficiency (Pilechiha, Peiman Mahdavinejad, Mohammadjavad Pour Rahimian, Farzad Carnemolla, Phillippa Seyedzadeh, Saleh, 2020). This paper presents a new, multi-objective method of analysing and optimising the energy processes associated with office buildings' window system design. The simultaneous consideration of multiple and conflicting design objectives can make the architectural design process more complicated. This study is based on the fundamental recognition that optimising parameters on the building energy loads via window system design can reduce the quality of the view to outside and the received daylight – both qualities highly valued by building occupants. This paper proposes an approach for quantifying Quality of View in office buildings in balance with energy performance and daylighting, thus enabling an optimisation framework for office window design. The study builds on previous research by developing a multi-objective method of assessing a reference room is parametrically modelled using actual climate data. Pareto Frontier's method and a weighting sum are applied for multi-objective optimisation to determine best outcomes that balance design requirements. The Results reveal the maximum possible window to wall ratio for the reference room. The optimisation model indicates that the room geometry should achieve the lighting and view requirements set out in building performance standards. The research results emphasise the need for window system configuration to be considered in the early design stages. This exploratory approach to a methodology and framework considers both building parameters and the local climate condition. It can be adopted and further refined by other researchers and designers to support complex, multi-factorial design decision-making. The research gap in this study states that designing modern buildings requires consideration of many different trade-off factors. Whilst there is an expectation that buildings should provide, comfort, and support their users' well-being, perform sustainably throughout their life-cycle. The minimisation of energy use is a range of increasingly valued factors expected, a value reflected in building regulations and requirements. Architects and decision-makers need decision-making tools to be enabled to effectively balancing competing factors. Window design is a complex optimisation task due to its contribution to building energy performance, day lighting and QV, particularly in office spaces. As the literature survey in this section shows, ample research optimises combining the two objectives, mostly day lighting and energy usage. QV is notably absent as a window design objective being measured or considered. Based on the literature, a comprehensive optimisation approach faces two main challenges: lack of a method to evaluate QV as numerical values properly and assess tools' interoperability. Therefore, this paper lays out a widely-applicable framework to assess the QV in the office environment and an approach to consider three main factors in designing windows.

The research methodology applies a multi-objective optimisation method to maximise the energy performance, daylight and the quality of view outside of an office environment, across different window system scenarios. The window system design problem's objective functions were the building energy loads for lighting, daylighting, and view to the outside. For the office room simulation, the 3D graphics software Rhinoceros (CCAA, Concrete Basics A Guide to Concrete Practice, Cement Concrete & Aggregates Australia, Sydney, Australia, 2010) Grasshopper plug-in software used to control the parameters. Parametric models are useful for design exploration in complex and dynamic design settings are window location and dimension in this study(Dino I. Creative design exploration by parametric generative systems in architecture. Middle East Technical University J Faculty Arch 2012;1:207–24). SDA and ASE metrics quantified and evaluated annual daylighting performance. These indices are contradictory to each other, and it is not possible to calculate one metric for representing daylight. Office energy consumption as a function of its conditioned floor area used the Energy Use Intensity (EUI) as the metric. So, EUI in this study is the sum of normalised heating, cooling, electric equipment and electric lighting load in a year (Kwh/m2/y). The view of outside assessed using the proposed QV metric. Hence, the optimisation process considers four different functions in the optimisation process. The daylight and energy metrics were extracted and calculated using Grasshopper plug-ins, namely Ladybug and Honeybee Honeybee(Fang Y, Cho S. Design optimisation of building geometry and fenestration for day lighting and energy performance. Sol Energy 2019;191:7–18).

These simulation tools used Energy Plus (Dino Ipek G, Üçoluk G. Multi-objective design optimisation of building space layout, energy, and daylighting performance. J Comput Civil Eng 2017;31(5)) and Open Studio(Zhai Y, Wang Y, Huang Y, Meng X). A multi-objective optimisation methodology for window design considering energy consumption, thermal environment and visual performance. Renew Energy 2019;134:1190–9) engines for energy simulations. For ASE calculation, a different algorithm was developed in Grasshopper, to use EnergyPlus weather file of Tehran and determine the direct illuminance in the horizontal plane, recorded at the end of each hour. Then the average illuminance for each hour is calculated. In the next phase, sun vectors plotted for hours, which is more than 1000 lx. The hours in which the sunlight hits the test surface (similar to the one used in daylighting analysis) simulated using sun vectors. The number of hours of direct sunlight received by each of the test surface test points, the portion of the space below 250 annual hours, is calculated. As mentioned in the research, the view performance has been under-investigated in previous studies; therefore, this study was the first to develop a framework for quantifying this objective. The optimisation objective function extended fitness functions introduced and applied earlier, using the weighting method. To find the optimum solution in Pareto front solutions accurately (Konis K, Gamas A, Kensek K. Passive performance and building form: An optimisation framework for early-stage design support. Sol Energy 2016;125:161–79.,Toutou AMY. A Parametric Approach for Achieving Optimum Residential Building Performance in Hot Arid Zone Faculty of Engineering Department of Architectural Engineering, Alexandria University. 2018)

The research presented in this paper addresses the theoretical and methodological gap in configuring window systems for office buildings' design. The design of window systems directly affects aspects of a building's quality and performance, including building energy performance, daylight gain, and visual comfort. The evidence on the optimisation of window system design has focused on energy performance and daylight aspects of windows. The research gap recognised from this research is that there is an opportunity for further studies to investigate the impactof shading and light control strategies on the studied optimisation objectives. Adding shading devices to facades provides an opportunity for simultaneous reduction in radiation transmission and heat gain energies and a higher capability to control daylighting (Hashemi A. Daylighting and solar shading performances of an innovative auto- mated reflective louvre system. energy Build 2014;82:607–20). However, the effects of such devices (e.g. blinds, screens, and shutters to the glazed surfaces, and implementing control strategies) on the quality of the view to outside have been under-researched. Future research could also explore variations in the building's external environment and understand the resulting impact on the triple analysis of daylight, visibility, and energy. The view indices examined in this research design were internal, and external indices such as view content and external distance not considered in this study. In future research, the points to be considered when assessing the quality of view and more precise contextual. Research conducted on building design elementson natural lighting performance in badminton indoor field Bumi pancasona kbp BandungStates that a good design of light holes buildings can maximise natural lighting potential in tropical countries,(Ali; Ariani Mandala, Safira,2020). The building of badminton sports is one of a vast span building's functions sensitive to natural lighting. It requires special techniques in incorporating natural light into it because of its wide span. There are three aspects of visual comfort that must be met by a lighting design in badminton sports buildings, namely 2% daylight factor, the distribution of illumination and glare effects. The three aspects of visual comfort were the point of this research and the research variable. This study aimed to determine the effect of design elements on natural lighting performance on the Pancasona Sportcenter Earth study object by exploring design elements. The study was conducted by evaluating the object of study's performance and analysing the influence of site and building elements on natural lighting performance in buildings. The evaluation of natural lighting performance in the study object establishes that the design elements that influence natural lighting on the badminton court. Exploration did by simulating the Velux computer program to create controlled conditions. The study object has not reached the applicable visual comfort standard with a 0.1% daylight factor value based on the evaluation results. The distribution of illumination was not uniform, and there was no glare. Design elements that could improve visual comfort in buildings are the net's position on the building's interior, the width of the openings, and the position of the opening in the building; these three elements a must to further investigation to improve visual comfort. The exploration results that provide the closest standard value are an exploration of the sawtooth type design, with the value of daylight factor 1.1%, the distribution of illumination most evenly between all explorations and no glare on the field the year. Based on exploration results, each design element could improve the performance of different natural lighting depending on the needs of the building and space activities.

Research conducted on a luminous environment with prism daylight redirecting fenestrations in classrooms (Tian, Zhe, Lin, PengHe, Ying*et al.*,2020). This study explored the luminous classroom environment with prism daylight redirecting fenestrations. The differences between the International Commission on Illumination standard sky and the Perez all-weather sky models were analysed. The study described the method of generating a valid bi-directional scattering distribution functions.xml data for the prism daylight redirecting fenestrations. A new evaluation metric, daylight evenness, was proposed to describe indoor illuminance dispersion. The analysis results indicated that prism daylight redirecting the fenestrations clerestories can improve indoor illuminance uniformity and daylight evenness when the solar altitudes range from 23.8° to 75°—an method of combined field questionnaire and high dynamic range image analysis for discomfort glare study. Adding a diffused layer to the prism film clerestory was expected to alleviate discomfort glare for east- and west-facing prism daylight redirecting fenestrations clerestory with the daylight glare probability reduction of 3.8% to 21.7% at various solar altitudes. The research results gave better advantages of applying prism daylight redirecting fenestrations at classroom clerestories to improve the daylight luminous environment.

This study concluded with analysing, the differences between the CIE sky model and the Perez all-weather sky model on the impact on PDRF daylight systems. With the PDRF daylight clerestory and conventional glazing, the space illuminance values were calculated at various solar altitude angles. Analysis results indicate that the micro-prism film system can achieve an improvement of illuminance level at the classroom reference plane about 23.2% and 15.4%, and the micro-prism film plus diffuse layer can increase the illuminance level at the reference plane around 18.7% and 10.6% under the CIE clear sky and Perez sunny sky, respectively. Modelling a PDRF system with the CIE clear sky condition may overestimate the indoor illuminance levels.

To analyse indoor daylight illuminance distribution, a new evaluation method and the associated index of DE has been proposed in this study, representing the standard deviation with logarithmic operation for the dispersion of the illuminance values on the reference plane relative to the average illuminance value. The analysis results for various solar altitudes indicate that the method may better describe the indoor illuminance dispersion conditions, especially for extremely low solar altitude conditions; the low illuminance uniformity value of 9.46% at the solar altitude of 11° may provide misleading information of indoor illuminance distribution.

The research results revealed that the PDRF could improve the classroom daylit luminous environment to increase illuminance uniformity and alleviate discomfort glare, especially for south-facing classrooms. Research conducted on An investigation of optimal window-to-wall ratio based on changes in building orientations for traditional dwellings (Chi, Fang'aiWang, Yongh, Wang, *et al*., 2020). The ratio of glazing and opaque areas on building facade had a significant impact on the indoor visual and thermal comforts as well as energy consumption; the optimal Window-to-Wall Ratio is necessary to be explored for the rural residences with a large quantity in China. Due to the traditional dwellings representing housing samples among rural residences, Sizhai traditional dwellings situated in Zhejiang Province were chosen as the study buildings in this paper. The building model is rotated to 20° increments clockwise to create 18 building orientation intervals. Furthermore, the Window-to-Wall Ratio of the front facade for the building model was divided into eight intervals at increments of 0.1, from (0.1–0.2) to (0.8–0.9). The daylight factor, air temperature, and air velocity were determined for the test scenarios with different building orientation and Window-to-Wall Ratio combinations through indoor environment simulation. Three optimal intervals of Window-to- Wall Ratios at a series of building orientations corresponding to the daylight factor, mean maximum indoor temperature and mean indoor air velocity are determined respectively, based on the criteria of national codes and thermal comfort ranges. The intersection interval of the three subsets was the optimal interval of Window-to- Wall Ratio for the study of the building. Also, for verifying the accuracy of research results, two validation techniques (i.e., comparison of experimental measurement data, and comparison of computational results from other simulation tools) were adopted in this paper.

The research was conducted on traditional dwellings located in Sizhai village with latitude29°34′ North and longitude 120°26′ East. Using the software of Ecotect 2016 and PHOENICS 2012, threeevaluation parameters of indoor DF, mean maximum indoor temperature and mean indoor air velocity was computed for each of the test scenarios with different BO-WWR combinations. Three optimal intervals of WWRs at a series of BOs corresponding to the three evaluation parameters were determined respectively, based on the criteria of national codes and thermal comfort ranges.

The intersection interval of the three subsets is determined as the optimal interval of WWR for dwellings. For research, two validation techniques were adopted. The first was by performing field measurements for the three evaluation parameters to conduct data comparisons. The experimental measurement data is regarded as “true data” and a powerful validation tool (Jensen, 1995). After verification through data comparisons, the software of VELUX Daylight Visualizer 2, Archi WIZARD 3.1.1 and Fluent 6.3.26 were used to provide another approach to verify the accuracy of research results virtually. The conclusion of the research is since the ratio of glazing and opaque areas on building facade has a significant impact on the indoor visual and thermal comforts as well as energy consumption, the optimal WWR is necessary to explore for the rural residences with a substantial quantity in China. Through software simulation, the DF, air temperature and air velocity were computed for each test scenario. Three optimal intervals of WWRs at a series of building orientations corresponding to the DF, mean maximum indoor temperature and mean indoor air velocity are recommended respectively, based on the criteria of national codes and thermal comfort ranges. The intersection interval of the three subsets is the optimal interval of WWR for the study building. In addition, for verifying the accuracy of research results, two validation techniques (i.e., comparison of experimental measurement data and comparison of computational results from other simulation tools) were adopted in this paper, and found that the research results are with a high reliability.

Another research was conducted on Architectural Designing with Green Daylighting Technologies to Achieve Savings in Cost Energy (El-hafeez, Mostafa AbdYoussef, Wagih FawzyEl-enein, Usama Abu, 2020). The research was done on the recent architectural trends to the integrate and friendly coexistence with the naturalenvironment and stop the voracious and gluttonous exploitation of its resources. Saving energy and the efficient use of renewable energy resources is one of the main strategies in sustainable architecture. A successful building design is characterised by its ability to minimise energy consumption and depend on renewable energy resources like sun and daylight. Green lighting is a term sited by the researcher under the heading of green architecture and sustainable design; it refers to using green renewable resources such as solar energy for admitting daylight into buildings to countervail between the external daylighting levels and the interior ones. The research concentrates different types of technologies on solar illumination systems that can beused to light the interiors of buildings. Some are suitable for introducing sunlight to the perimeter zones, or the top floor or two top floors of multi-story buildings. Others can illuminate the core areas of multi-story buildings. All of those systems could be employed together to serve a daylighting system of a building. Green lighting technologies is just a technology that uses the potentials of modern sciences and technologies with the respect of the value of the environment.

Lighting energy conservation is an essential part of green lighting, and its purpose is to make full or almost use of such safe and clean sunlight and skylight for illuminating interiors to save lighting power. Those technologies allow daylight to illuminate buildings during the day and convert sunlight into electricity to illuminate the building when sunlight is not available and during night hours. The site, the orientation, and the form of thebuilding are essential aids in determining the quantity of daylight can penetrate the building. They are referred to here as the fist technology named Urban Morphology. The second type of technology is the Beam Daylighting Systems; they employ devices to modify light's behaviour, introducing it to distances exceeding distances introduced by conventional systems. Some channelling systems carry daylight from outside to the remote areas of buildings. Those systems are presented as Daylight Transport Systems, the third type of technology to support the green initiative in reducing the energy requirements. The fourth technology Support systems play an assistant role in capturing, collecting, and concentrating sunlight presented as Daylight Collection Systems. Photovoltaic Lighting System supplements the whole technology to guarantee to do without artificial electricity.

For Designing buildings with green lighting system acomputer software were designed to assistdesigners to incorporate green daylighting systems into their building design to obtain the main three goals of the green systems; human health and well-being, electrical energy reduction with both lighting load reduction, and cooling load reduction, and environment preservation by reducing the harmful carbon dioxide emissions. The program – named Green DaylightingProgram GDP – is basing on a mathematical equation concluded by the statistical program. That equation was concluded subsequently based on comparative analyses of green systems composing the green lighting technologies. Systems that will be analysed are systems composed of beam daylighting systems and daylight transport systems. Beam daylighting systems used redirecting the sunlight by adding reflectors or refracting elements to the conventional window. These additional elements modify the usual behaviour of natural light by redirecting it towards the room ceiling. This allows light to penetrate the buildings' core areas not normally accessed by conventional windows to reach up to 12 meter light penetration distance. Significant of These elements rejects sunlight and transmit diffuse light to buildings interiors, so they control heat gain and glare problems. These systems were ; Optically Treated Light Shelf, Sun-Tracking Light Shelf, Louvers and Blind Systems, Prismatic Panels, Laser-Cut Panel, Angular selective sky light, Light- Guiding Shades(LGS),Sun-Directing Glass,Zenithal Light-Guiding Glass with HOEs, and Anidolic daylighting systems. Day light transport systems used the development of efficient daylighttransport systems to transport solar light over distances of many meters. It offers the possibility of providing high-quality natural daylight to the interior, core, and space of multi-story buildings. Suppose these piped daylighting systems are designed into the buildings from the beginning. In that case, costs can be kept under control, and the usual difficulties can be minimal, as mentioned in the research. A green daylighting programme used statistical methods used in the data analysis: SPSS software. The main objective of using SPSS is to deduce an equation depending on a set of variables (the terms of the equation) to find out the case/cases or the system/systems that can be used in buildings basing on specifications of cases (systems) that are expressed in the form of variables. Many statistical methods areused in the field of data analysis. The methods that are applied in this study are including the factor analysis and the regression analysis.

The research concludes that the current directions in architecture towardsgreen buildings imply sustainable design and healthy environment for people. The extensive use of daylighting to meet the ambient illuminationrequirements is nearly always a part of “sustainable” buildings. The study analysed existing new innovative daylighting technologies solutions and constructed a new design tool to help the designer integrate those green daylighting systems into his building's architectural design. That tool is representing in computer software designed by the researcher to ease the necessary design process and make it accessible. The utilised mean to achieve that is by constructing a data matrix that is formularised from the concluded comparative analysis table. By analysing the data statistically to elicit mathematical equation that can help designers evolve the proposed green daylighting systems in their buildings by just insert some building's information. The statistical analysis was done by Statistical package for social sciences (SPSS) software program. The constructed program is named Green Daylighting program, with an understanding that program will represent the base for a comprehensive green daylighting design for buildings in the age of green revolution.

A research conducted on Design strategies and energy performance of a net-zero energy house based on natural philosophy (Shi, FengWang, ShaosenHuang, *et al.* , 2020).This paper presented the design strategies and energy performance of a net-zero energy house (NZEH), Nature Between, which was designed and built to participate in the Solar Decathlon China 2018 competition. The specific parts of the design strategies for Nature Between, including architectural concept, materials, passive strategies and active strategies, are introduced and analysed. This study includes a discussion of the building’s energy performance based on the measured data gathered in Dezhou, where the competition was held. And also the annual energy simulation using Energyplus software based on the climate of Xiamen, where the prototype was located in. The results show that the design strategies are reasonably applied in Nature Between to achieve the goal of zero energy consumption in Dezhou and Xiamen. Pleasant indoor environment and flexible spaces are achieved in the house using natural material, which embodies the concepts of sustainability and natural philosophy. The practical strategies provided in this paper could help the architecture designs for residential NZEH.

Understanding more about ZERO ENERGY HOME presented in the literature review descries the about the term “Zero Energy House” that was proposed by (Torben V.Esbensen ,1976 and Esbensen and Korsgaard 1977). Since then a lot of studies have been conducted on different aspects of the subject, such as design strategies (Belussi *et al*. 2019; Fatima, Farouk, and Henry 2018); Longo, Montana, and Sanseverino 2019), new material (Stritih *et al*. 2018), technologies choices (Feng *et al*. 2019) and energy performance (Cao, Dai, and Liu 2016). DOE introduced the concept of net-zero energy house and promoted it by hosting Solar Decathlon competitions. The practice of NZEH gradually spread to many areas with different climatic conditions (Lan, Wood, and Yuen 2019; Uk-Joo and Seok-Hyun 2019; Wang, Gwilliam, and Jones 2009). Because of the comprehensive and interdisciplinarycharacter of Solar Decathlon competitions, many studies were carried out based on the houses built in the competition. Some research papers focused on solar energy technologies, such as new photovoltaic and solar thermal technologies (Aldegheri *et al*. 2014; Young, Chen, and Chen 2014; García-Domingo *et al*. 2014; Iimura, Yamazaki, and Maeno 2014) and building integrated photovoltaic (BIPV) design strategies

(Cronemberger *et al*. 2014, 2014; Chen, Athienitis, andGalal 2010). Research on the application of energy efficient HVAC equipment (Fiorentini, Cooper, and Ma 2015; Real *et al*. 2014; Kazanci *et al*. 2014) and new materials such as PCM materials (Rodriguez-Ubinas *et al*. 2012; Lin *et al*. 2014) were also becoming popular. Other studies focused on the integration of various energy efficient technologies (Wang *et al*. 2009; Peng *et al*. 2015a; Bohm 2018; Zhang *et al*. 2014), as well as passive design strategies to reach the net-zero energy goal (Wang *et al*. 2016; Irulegi *et al*. 2014; Rezaian *et al*. 2015; Rodriguez-Ubinas *et al*. 2014). The performance of Solar Decathlon houses has also been discussed in many articles, including indoor thermal comfort (Brambilla *et al*. 2017), lighting environment (Berardi and Wang, 2014), energy performance (Cornaro, Rossi, and Cordiner *et al*. 2017; Peng *et al*. 2015b; Shrestha and Mulepati 2016) and electrical systems (Iimura, Yamazaki, and Maeno 2014).

Design Strategies in the research used the following

- The Architectural concept : The architectural concept of Nature Between is targeted for an old house in an urban or rural village that needs to be transformed into a better living space for a more comfortable life.
- Materials : Materials were carefully chosen for each part of the house to make it more sustainable and easily built by the students.
- Wood : As a traditional Chinese building material, wood is widely used in China and easy to build.
- Straw insulation : Straw is an agricultural byproduct that is readily available in rural China. Compressed straw panels are used in the building for their good thermal insulation properties and good acoustic performance. They are also cheap, easy to process, and perfectly recyclable.
- Phase Change Material : For the convenience of disassembly and transportation, most houses in the Solar Decathlon use light materials in walls with poor thermal stability. Therefore, the houses have difficulty in resisting the impact of outdoor climate change. To address this problem, phase change materials with a phase transformation point at 23°C are used in the sidewalls of the inner yard of Nature Between. The heat storage capacity of the materials is used to achieve a more stable air temperature in this unconventional yard.
- Other Materials : Bamboo is used in the folding doors of the gallery yard, which are similar to traditional Chinese- style folding doors, and also as a dynamic shading facade for the building. Windows: Low-E triplepane hollow glass is used forthe doors and windows of Nature Between. Vacuum glass is used for the two outside layers of the glass, and the hollow layers are filled with argon gas.

Passive strategies used in the research were as given below

- Climate Analysis : Nature Between is designed by integrating low-tech and high- tech technologies using the key elements of bioclimate architecture, such as shading, natural ventilation, natural lighting, and rainwater recycling. The house is able to regulate its air temperature, humidity, air quality, lighting, acoustic and other comfort aspects in a passive way. The design strategies are based on the climate of Xiamen and the weather in Dezhou in August for the competition.
- Themal Buffer Space : The design strategy of a buffer space (Dekay and Brown 2014) is used in the inner yard located at the main entrance of the house. The inner yard connects most of the indoor conditional spaces of the house and serves as a thermal buffer between the indoor and outdoor environment.
- Dynamic Shading : The climate of Xiamen is hot and humid with high solar radiation intensity in the summer, and the same was true in Dezhou during the competition.
- Natural Ventilation : Natural ventilation can remove heat and humidity from the house and improve indoor thermal comfort conditions when the outdoor climate is comfortable. This is particularly important in the climate of Xiamen and is also an important factor for thermal comfort control.
- Natural Lighting : The design of natural lighting is also an important issue in Nature Between. Lighting design is based on the simulation results to guarantee a daylight level of 300lx for the main accommodation rooms. The lighting level inside the house can be regulated through the dynamic shading systems to ensure indoor lighting comfort.

The Active strategies used in this research are as given below

- **BIPV System:** Solar panels were the only energy source in the competition, so BIPV design is especially important for the house. Fifty-four photovoltaic panels and two solar thermal panels for water heating are installed on the roof of Nature Between, emphasising the design concept of building integrated photovoltaic systems.
- **HVAC Systems:** The HVAC system is critical in the design of zero energy buildings, because normally its energy consumption accounts for 50% to 70% of the total power consumption of the house, and it affects the indoor comfort and air quality directly.
- **Control Systems:** An intelligent control system which supports the KNX protocol is used in the house to control the active equipment and many parts of the facade for shading and ventilation. The aim of the automated systems is to integrate the passive systems such as the dynamic shading, and the active systems, such as the HVAC equipment and the electrical appliances, to reach the comfort level specified in the competition rules and to allow the building to consume less electricity than it generates.

The conclusions of this research states that by analysing the design concepts and energy saving technologies of Nature Between, exhibits a method of using comprehensive strategies to achieve the goal of zero energy consumption in buildings. The practical strategies provided in this paper could help architecture designs for residential NZEH. Research conducted on A dimensionality reduction method to select the most representative daylight illuminance distributions (Kent, Michael G. Schiavon, Stefano Jakubiec, John Alstan, 2020. The research presents a challenge when evaluating daylight distribution is dealing with the large amount of temporal and spatial data, visualisations and variability in illuminances that are assessed in buildings. Using a dimensionality reduction method based on principal component analysis, we identified the most representative annual daylight distributions. The researcher modelled a rectangular room containing an analysis grid of 3200 illuminance sensor points and simulated 3285 different temporal daylight conditions using an annual occupancy schedule ranging from 08:00 to 17:00 with one-hour sampling intervals in two locations: Singapore and Oakland, California. Their approach explained 98% of the illuminance variability with three daylight distributions in Singapore, and 92% using six in Oakland, California. Their dimensionality reduction strategy was also generalised using a complex building geometry showing the utility of the method. The researcher thinks that this approach could be used to provide a more efficient and reliable method to analyse daylight performance in building practice.

The researcher in the research had done some review on the illumination which is described in detail, illumination that is received on the horizontal work surface is designed so that it meets a certain minimum criterion, is uniformly distributed, and does not cause visual discomfort. These criteria are not always met, since daylight from side-lit openings can cause significant changes in the light levels received on the indoor surfaces (Constantatos, 1982). Daylight distribution is dependent on a number of variables, for example, how light interacts with the geometry of the building, building façade geometry and optical properties, and changes in the outdoor conditions (Lee, DiBartolomeo, and Selkowitz,1999; Mardaljevic, Heschong, and Lee,2009). This creates a luminous environment that continuously undergoes dynamic changes and Annual daylight metrics – commonly referred to as Climate-Based Daylight Metrics (CBDM) have been developed to evaluate the performance of natural light inside buildings. These can be used to calculate a percentage time of the year in which daylight meets predefined targets based on meteorological weather data (e.g. Daylight Autonomy, Useful Daylight Illuminance, etc. (Nabil and Mardaljevic ,2005, 2006; Reinhart, Mardaljevic, and Rogers,2006)). Since these summarise the performance of day- light into a single value, information regarding the distribution of daylight can be lost in these processes. Although it has been suggested that light distribution is an important design consideration (Boyce, 2014), there are limited daylight metrics that have been designed to evaluate a range of luminous effects that occur across the annual occupied hours of a building (Rockcastle and Andersen ,2014).

While the introduction of daylight in buildings can be used to indirectly offset electric lighting usage through the use of sensors and control systems (i.e. dimmers and illuminance sensors) (Kamaruzzaman *et al*. ,2015;Xue,Mak,and Huang ,2016), this is not only dependent on whether the daylight can meet and does not exceed the design illuminance value but also on its spatial distribution throughout the entire occupied space. In fact, (Yun *et al*. ,2012) suggests that energy use from artificial light can be reduced by 30% when lighting controls are care- fully designed in relation to indoor daylight distribution levels. Although studies will often aim to improve daylight distribution inside the occupied space (Doulos, Tsangrassoulis, and Topalis,2008; Freewan,2010), these rely on the calculation of a uniformity criterion. Researchers studies that there are several methods of calculating the uniformity of daylight distribution on the horizontal work surface. The aim of uniformity criteria is to ensure illumination is distributed evenly across the space (Littlefair, Aizlewood, and Birtles,1994). Although furniture is usually not considered in the analysis and uniformity calculations only take the daylight received at the horizontal surface at a predefined height from the floor (Ryck- aert *et al*. ,2010), the IES-LM-83-12 (Daylight Metrics Committee,2012) method recommends that furniture that is at least 0.91m in height should be included. Researcher studies on the various calculation methods from various literature review ,the scientific literature contained many methods of describing daylight distribution and there are many widely accepted approaches used to measure uniformity (Lynes, 1979). One such method of measuring daylight distribution that is recommended by the Society of Light and Lighting is to calculate the uniformity criterion by dividing the minimum and maximum illuminances. illuminances found on the horizontal work surface (SLL, 2012). It has also been suggested that uniformity can also be calculated from the minimum to average illuminance ratio (Bean 1975; Constantatos ,1982). The code for interior lighting (CIBSE, 1994) suggests both approaches of calculating uniformity. When it is believed that uniformity may be difficult to achieve, then the minimum to average illuminance should be the preferred criterion. However, recommendations of what is considered to be appropriate levels of uniformity (i.e. 0.5–0.7) are originally based on a study in an artificially lit room masked from the influence of daylight (Slater and Boyce ,1990). Uniformity based on the same ratios may also be calculated with the room's equivalent Daylight Factors under an overcast sky (Lynes 1979). However, caution over the results has been advised since under any other sky condition, daylight uniformity will significantly worsen com- pared to an overcast sky (Dewey and Littlefair ,1998). These criteria of calculating uniformity are generally defined as extreme value-based (Yao *et al*. ,2017) suggests there are two alternative methods of estimating uniformity, namely, statistical and pattern-based.

(Mathieu ,1989) proposed the statistical uniformity (SU) that is calculated according tothe equation given below. This makes use of the standard deviation (σ) and average mean illuminances (Ex) on the horizontal plane. The author showed that the SU does not vary when the size of the analysis grid changes but does when the minimum to average illuminance ratio was used. Another similar proposal by Armstrong,1990) divides the mean illuminance by the standard deviation, which gives the criterion called the coefficient of variation (CV). Since these criteria do not rely on extreme illuminances values, they are not influenced by the minima and maxima illuminance values.

$$SU = \frac{Ex+\sigma}{Ex-\sigma} -\infty \leq SU \leq \infty \text{and } SU \in R$$

The SU criterion can potentially take on a large range of values, which makes it difficult to interpret. A third statistical method of calculating uniformity given by Mahdavi (1997)is the uniformity factor (UF), which ranges from values between zero and one:

$$UF = \frac{Ex}{Ex+\sigma} 0 \leq UF \leq 1 \text{and} UF \in R$$

The third criteria group are pattern-based (Mahdavi and Pal,1999) argued that a limitation of extreme value and statistical methods is that they cannot be used to estimate uniformity when the horizontal surface contains different spatial patterns (i.e. complex illuminance distributions on the horizontal surface). They proposed an entropy-based index (EBI) that calculated the illuminance distributions from global and local areas of analysis grid. These can be used to calculate the topological illuminance distribution of a target grid area. However, it has been argued that the EDI cannot distinguish visual patterns the same way the human eye can (Wang *et al*., 2004). Regardless of the complexity of the uniformity criteria, researchers believe they provide a limited description of how daylight is distributed in buildings because they need to reduce it to a single numerical value. On the horizontal work surface, daylight causes a large variation in illuminance levels (Nicol, Wilson, andChiancarella,2006) and understanding this behaviour, beyond uniformity, is crucially when describing the luminous behaviour of any building (Tregenza 2017, 1986). This spread in the data is created by a high number of spatial and temporal dimensions that should be fully considered when the daylight distribution is evaluated. Spatial dimensions can be defined by the set number of analysis points used to capture illuminances on the horizontal surface, which can be calculated or specified according to recommended guidelines (BCA Green Mark, 2016; Daylight Metrics Committee ,2012; SLL, 2012). Temporal dimensions are those that vary across the occupied hours. While many studies evaluate daylight under a limited number of conditions (i.e. equinoxes or solstices (e.g. Canziani, Peron, and Rossi, 2004; Free- wan ,2010; Freewan, Shao, and Riffat, 2008; Sun, Wu, and Wilson 2017; Ullah *et al*. 2017; Zhu *et al*. 2018)), there are an enormous number of temporal dimensions (i.e. month, days, hours, etc.). As time varies, there are constant in the sun position, cloud pat- terns, weather, etc. that can significantly influence the daylight conditions inside any given building (Tregenza,1999).

Researcher think that daylight uniformity should be evaluated by identifying themost representative illuminance distribution pat- terns on the horizontal plane across the occupied hours of the building. Representative daylight illuminance distribution patterns could be used to describe a large subset of different daylight illuminance distributions that form a statistical relationship with each other across a number of temporal dimensions. Since it is possible that two or more conditions can have the same degree of uniformity – as calculated by available criteria – but different daylight illuminance distributions due to temporal variation, an alternative method is needed to provide a better understanding of daylight performance. The researcher used Principal Components Analysis (PCA) to reduce a large number of correlated variables (i.e. dimensions) into smaller linearly related components, which are strongly correlated with each other (Field 2013). The components would give a compact description of the original data (Liang *et al*. 2002), thereby allowing complex high dimensional data to be more easily interpreted (Lever, Krzywinski, and Altman, 2017). In this research study, the principal components were groups of daylight illuminance distributions from different temporal conditions which are linear related to each other. Each principal component was independent from others and are derived from important simulation parameters (i.e. the building model dimensions and properties, time conditions, and climate data). Based on their approach researchers assumed that at each individual illuminance grid point is statistically related with the same grid point at a different time. When generalising this to all grid points across two conditions, the illuminances would be correlated.

Researchers findings have shown that existing uniformity criteriado not provide an informative description ofhow daylight is distributed on the horizontal surface. Although uniformity criteria can show how evenly daylight is distributed across the horizontal surface, they cannot distinguish that one illuminance distribution is significantly different from another. We think further research may be needed to evaluate how the use of these uniformity criteria influence the performance of daylight dimming sensors.

Conclusion

From all the above researches revies m it shows that there are various methods to increase the daylighting and increase the use of the natural resources through WWR , UF , and use of environmental friendly materials , all these researches had one objective in common , to increase the daylighting effects in homes, stadiums commercial buildings and green buildings thereby reducing the use of the externa energy sources to power the lightings inside the buildings or homes. The gap that could be established that similar research could be carried out in India for specific office buildings in India , as the power consumption pattern in these building needs to be reduced not only for the reduction in the operating costs but this would also contribute to the reduction of the Green house gases , lesser polluted atmosphere for the future coming generations

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