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Daylight illuminance in urban environments for visual comfort and energy performance

Nazanin Nasrollahi *, Elham Shokri

Architecture Department, Technology and Engineering Faculty, Ilam University, Ilam, Iran

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ABSTRACT

Daylighting is a passive strategy which is significant in increasing the liveliness, performance, and visual comfort of the residents. It helps to reduce the overall electrical energy consumption of a building. The absorbed radiation by the façade and building interior varies depending on different factors including the sky, environmental barriers, vegetation and position of the sun. The urban environmental factors are fairly effective in creating an appropriate visual space while reducing the energy consumption of a building. This paper aims to review the relevant literature including the basic concepts of daylighting, sky types, movement of the sun and effective architectural parameters in an urban context. The importance of these factors regarding daylight absorption by the facade and interior part of a building, visual comfort and energy efficiency are discussed thoroughly. The concluded results indicate that these factors are of high significance and their impact on the amount of daylight and energy consumption is undeniable. Based on the geometry of urban canyons (height to width ratio of a street), by increasing the street width, the amount of radiation reaching urban canyons significantly increases whereas the energy consumption reduces. In addition, by increasing reflectivity coefficient of materials in exterior surfaces of horizontal and vertical directions, the amount of daylight reaching the interior portions of a building is increased and the need for artificial lighting is consequently reduced. Exterior shading devices also provide visual comfort and decrease the energy consumption of a building. The amount of radiation (daylight) shone into a building is considered an energy saving option, which depends on the region climate. However, a street orientation might cause an uneven distribution of the general radiation on surfaces of the urban canyons.

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* Correspondence to: Architecture Department, Technology and Engineering Faculty, Ilam University, PO Box 69315-516, Ilam, Iran.
E-mail addresses: nazanin_n_a@yahoo.com, n.nasrollahi@ilam.ac.ir (N. Nasrollahi), Tdoshokry8847@yahoo.com (E. Shokri).

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1. Introduction

Daylighting is a significant parameter in lighting industry. It is an essential factor for granting the certificate of Leadership in Energy and Environmental Design (LEED)[1] [1]. Considering the proper process of design and its implementation, daylighting could perform as a natural adaptable light with the environment, otherwise illumination of the spaces becomes inefficient [2]. The importance of daylighting has had its mixed opinions throughout history. The debate on this topic started during beginning of the twentieth century, which introduced daylighting as a primary source of lighting and a special element in enhancing architecture [3]. Due to the low cost of lighting design, implementing florescent light came to attention during the post-war era [4]. Architects became interested in daylighting shortly after the oil crisis during 70's. However, this desire experienced a severe decline between 1980 and 1990 [3]. However, the efforts in modern architecture by owners and architects in order to increase the lighting of buildings lead to increasing daylighting usage [5]. In order to study daylighting in detail and obtaining a better insight regarding the past research, it is essential to conduct a comprehensive study about the previous research studies in this matter. However, this article is focused to research the general topics about daylighting, visual comfort and reduction of energy consumption (electrical) on urban scale. During the recent years, numerous research studies are conducted regarding daylighting and its specific effects on the urban environment. The majority of these studies are conducted in the past three years. This shows a growth of interest in the topic of daylighting and discussing it from various viewpoints, particularly architecture and energy aspects. The conducted studies and investigations regarding the completion of previous researches on daylighting, highly contribute in scientific growth and creation of efficient urban plans. In order to clarify this issue, the global research profusion is indicated annually in Table 1. The concise review of the topics and its corresponding research results that are conducted in duration of 1993–2015 are shown in Table 2.

As previously mentioned, Table 2 indicates the topics as well as results of the recent research projects on daylighting, specifically in the urban environments. Among these articles, the article written by Freitas and et al. published in 2015 [11] indicates some interesting facts, including using diverse methods of research like authentic up-to-date software, named Radiance [54], GIS [55]. The solar maps and its vast information about daylighting is another advantage of this research. However, these models have major limitations which require data enhancement in the future. It is essential to overcome such constraints in order to present detailed information about radiation, implementation of energy conversion modeling, improvement of data verification and enhancement of its relative data [11]. In addition, Sanaieian and et al. [16] in 2014 studied the proximities of buildings thermal behavior. They stated that the precise evaluation of this behavior is difficult, since simultaneous evaluation of the whole relative branches is highly complex. The majority of articles are focused on solar radiation and solar potential estimation on the urban scale. In 2013, in an article by Dereli and et al. [56], studied the growth of trees and their lifetime impact on the efficiency of photovoltaic solar tools. This article provides a new method for prediction of the shadow loss of any specific tree species. The investigated characters of the tree growth are: height, width of the crest and the growth rate. The minimum distance between the plants is measured according to the species of trees and its direction of planting. The obtained results of this research present that the shadows could decrease the outcome of the photovoltaic tools. This low cost method is used to protect efficiency of the photovoltaic roofs from the negative impacts of the trees' shadows. The simulation is done with google sketch up, due to its low cost and availability. In the articles [57–60,61], daylighting is researched in general; due to the lack of space they are just referred to concisely rather than a precise review of the topics. The general review of the literature regarding the lighting urges the need for prioritizing the daylight as an important research topic. The existing knowledge is restricted to the impact of external barriers on the amount of lighting and visual comfort outside and inside of buildings. However, study of the existing gaps and the major undiscussed topics are highly desired for future investigations. In general, daylight and visual comfort in the recent years are thoroughly investigated via simulations and other methods. Although, less research is done on architectural elements and reflection of materials outside of the buildings.

Table 1
Indication of annual profusion of global authentic scientific research about daylight in urban scale during 1993–2015.

Dissemination year of the articles	Profusion
1993,1994	1
1998,1999	1
2001	4
2002	3
2003–2005	1
2006	3
2007	2
2010	3
2011	4
2012	3
2013	9
2014	8
2015	**8**

[1] Leadership in Energy and Environmental Design.

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