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The Review of the Selected Challenges for an Incorporation of Daylight Assessment Methods into Urban Planning in Poland

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Abstract

The main objectives of this research it to find out if modern daylight assessment and design methods can be useful for urban residential planning in Poland. The study gives a chance to describe and appraise modern daylight design techniques. The other purpose is to illustrate how daylight knowledge could be used as an incentive to rethink the way urban environments are created. Although daylight design is acknowledged in literature and case studies as a tool for fostering residents' well-being, daylight design techniques are not common practice in Poland. A review of current Polish building and lighting regulations regarding daylight is presented. The results of the two pilot questionnaires show a lack of daylight training among future architects and urban specialists. The first survey carried out among 54 students illustrates the importance of daylight as a natural resource which is essential in sustainable approaches to urban planning. It also highlights the belief that daylight and electric light projects should be holistically integrated in the implementation of the city lighting plans. The results of the second pilot study show a growing demand for better daylight education and an urgent need for revision of the existing recommendations in Poland.

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1. Introduction

The idea behind this paper revolves around three questions. The first inquires if the daylight can be a driving force

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for reshaping the way modern residential areas are created? The second one ponders how to described daylight? The third question asks about the barriers for an incorporation of modern daylight assessment methods into residential urban planning in Poland.

The main objective of this paper is to describe challenges for an incorporation of modern daylight evaluation and design methods within urban residential planning in Poland. The paper is an excerpt from the PhD research, which focuses on daylight design methods and recommendations that could be applied into Polish building and lighting practice and regulations.

2. Background

2.1. Can daylight be a driving force for reshaping the way we design modern urban spaces?

The year 2015 was proclaimed the International Year of Light and Light-Based Technologies (IYL) by the United Nations General Assembly Committee [1]. One of the scientific events celebrating the IYL 2015 was 6th Daylight Symposium held in London. The motto for the Symposium was: *Daylight as a driver of change* [2]. During this event scientist, practitioners and regulators focused on the challenges faced by modern society in regards to daylight within urban environment. Many speakers (including Steering Committee Chair of IYL 2015 John Dudley), described daylight as a driving force which could help to rethink the way the urban environment was designed. The opportunities, challenges and responsibilities associated with daylight and building legislations were also introduced. Daylight was considered as a driving force form many perspectives: human factors perspective [3,4,5] sustainable design of the urban environment [6,7,8], technology [9], processes [10,11] and culture [12]. The massage repeated by many participants was that a role of daylight design in creating modern, healthy, comfortable, energy-efficient and smart lighting environment was essential [2]. Moreover, better understanding of daylight impact on architecture can reshape cities, creating healthier and more energy-efficient places to live. The greater interest in daylight in the last years is the result of two main drivers: the potential to save energy and a notion that daylight solutions affect well-being, health, mood and productivity.

2.2. How to describe daylight?

When daylight is seen as a driving force or a tool for reconsidering architectural and urban design it has to be precisely described. Therefore, the contemporary daylight design research mainly focusses on daylight availability, predictability and control, avoidance of glare, and overheating, as well as on the measurements of skylight general illumination, shading systems and daylight's energy efficient potentials. Majority of the research focuses on providing the daylight availability to a building. However, some of the studies discuss an influence of daylight design on an urban scale. Mark DeKay [13] asks: *What would the form of the city like of we were to take seriously the provision of daylight to all buildings?* He indentifies and explores an empirical relationship between daylight levels inside buildings and the street canyons rations – the daylight access rule and daylight envelopes. Others researchers [14,15,7,16], including John Mardaljevic [17] investigate daylight and solar access within a high density urban environment. Mardaljevic concludes: *the drive towards sustainable, low-energy buildings places increasing emphasis on the need for detailed daylight performance evaluations. This need ranges from useful guidance at the early design stage, to code compliance based on construction documents, to post-occupancy verifications* [18].

2.3. How daylight is presented in existing regulations?

The legal requirements concerning daylight in different countries are diverse. In 2012 the survey was carried out researching daylight national regulations in 16 countries. The findings showed that the most widely recognised international standards related to daylight were [19]:

- ISO 8995:2002 *Lighting of Indoor Work Places- 4.7 Daylight* (CIE S 008/E:2001)
- EN 12464-1 *Light and Lighting - Lighting of Work Places - Part 1: Indoor Work Places*
- BS 8206-2 *Lighting for Buildings. Part 2: Code of practice for daylighting*

The regulations associated with adequate or sufficient daylight in many European countries are covered by the national building codes. The requirements are in general based on average Daylight Factor or window to floor area ratio. The standards are informative and are used to provide guidance regarding best practice but are not intended to be applied in a prescriptive manner [19]. Among major initiatives for creating new more holistic and robust international regulations for daylight have been works carried out by Comité Européen de Normalisation (CEN), Commission Internationale de l'Éclairage (CIE) TC 3-47 and Illuminating Engineering Society (IES) in the US. Technical Committee of CEN TC169 WG11 within the European Committee for Standardization has been working currently on a new European standard for daylight.

The latest Polish daylight standard PN-71/B-02380 *Natural Interior Daylighting Code of Practice*, which described general conditions of daylight distribution within interior spaces, Daylight Factor (DF) calculations, daylight coefficients, and DF values for different visual tasks as well as glass transmittance and reflectance values [20], was withdrawn on 24.10.2005 [21]. Daylight is mentioned in the Polish building and health regulations (Tab.1).

Table 1. Overview of current Polish building regulations in regards to daylight[1].

Regulation title	Subject covered
The Minister of Infrastructure Regulation dated 12 April 2002 on the technical conditions to be met by buildings and their location (Journal of Laws 2002 No. 75, item. 690)	Reg. 206 specifies the conditions for exposure to sunlight in regard to room function: In permanently occupied rooms, the provision of daylight should be at least 3 hours long during equinox days (21/03 and 21/09) between 7am and 5pm. For multi-family apartments, the lower limit of daylight time in at least one room is set at 1.5 hours, while in single room apartments, no insolation time is required. In permanently occupied rooms, the ratio of window area to floor area (WFR) should be at least **1:8**, and in any other room, where daylight is required, the ratio should be at least **1:12**. The legislation foresees the exemptions when: 1. Daylight is not necessary or is not desirable due to applied technology 2. There is a need for functional spaces in the underground facility or part of a building with no access to daylight. Art.13 specifies the conditions for distances between buildings in order to guarantee access to daylight: **D ≥ H** for obstructing objects no higher than 35m; **D ≥ 35 m** for obstructing objects higher than 35m. For downtown infill buildings, the distance (D) can be decreased by half. Where: H is the obstructing height and is counted from: the lower edge of the lowest windows in the obstructed building to the level of the highest edge of the obstructing.
Decree-law of Minister of Health from 29 June 2012 Position 73; 26 June 2012 concerning detailed requirements for premises and equipment entity engaged in medical activities	Chapter 5 Lighting § 33. In the rooms with beds a direct access to daylight should be provided. § 34. In those rooms the special daylight protection equipment should be installed in a case of excessive daylight exposure. § 35. 1. In the operating theatres and diagnostic imaging areas only electric lighting should be applied 2. Daylight is allowed if it does not cause any diagnostic problems.

Other lighting standards in Poland, where daylight is mentioned are: PN-EN 12464-1:2012 *Light and Lighting - Lighting of Work Places - Part 1: Indoor Work Places* and PN-EN 12665:2011 *Light and Lighting. Basic terms and criteria for specifying lighting requirements.*

3. State of art- selected daylight performance indicators and metrics

The development and evolution of daylight performance indicators, metrics or calculations methods or daylight systems are described by many [22,23,24,25]. The demand for accurate methods which evaluate 'daylight' environment and their precise descriptions has increased recently due to a need of creating low-energy buildings where human comfort performance is respected. The daylight performance metrics are considered in aspects of: daylight availability and distribution, sunlight exposure, visual comfort, freedom of glare and outside view.

[1] Text translated from Polish by BPIE in their publication *Indoor air quality, thermal comfort and daylight. Analysis of residential building regulations in eight EU member states* from 2015, p.76 and by the authors of this publication.

It has to be reminded that daylight illumination levels changes constantly in terms of their intensity and spatial distribution patterns. Daylight is also heavily depended on physical properties of the space, geometry of the building, its geographical location and climate. The ways to describe daylight and the definitions of performance parameters depend on conditions against which the performance should be compared. The physical features including size and location of the windows sunlight and skylight interrelations outside building influence the quality of daylight inside building. Most of the described below daylight metrics focus on availability and quality of light within building interiors. However, the decisions about an orientation of building patterns, building placements and forms are part of urban design. Therefore, the daylight metrics have to be investigated in regards to inside and outside conditions[†].

The most popular quantitative metrics of daylight include Daylight Factor (DF), outside view and the avoidance of direct sunlight. The building performance rating systems like the BRE Environmental Assessment Method (BREEAM) and the Leadership in Energy and Environmental Design (LEED) in their good daylight practice criteria suggest the usage of DF, glare control, minimized solar heat gain, glazing factor, also Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) as metrics which help assessing building energy performance (Tab. 2). Dissatisfaction associated with the DF limitations and popularity of 3D CAD software and computer simulations led to a development of the concept of Climate Based Daylight Modelling (CBDM) and based on it alternative dynamic daylight performance metrics like Useful Daylight Illuminance (UDI).

Table 2. Selected daylight metrics/indicators.

Selected daylight metrics	Characteristics
Daylight Factor $\overline{\text{DF}}$, DF, Major publications: A.P. Trotter, Daylight Factor Concept was first introduced (1895) A.P. Trotter, Illumination, Its Distribution and Measurements, London: Macmillan, 1911. P. Moon, D. Spencer, Illumination for a Non-Uniform Sky. Illuminating Engineering (1942)Vol. 37 (10): 797-826	Daylight factor is defined as the ration of the illuminance at a point within a building. For the Standard Overcast Sky daylight factor is the sum of three components: the sky component, the internally reflected component and the externally reflected component. DF is expressed as a percentage [23,26]. The average daylight factor (the mean daylight factor over a given area of the room) for interiors is recommended at least 2 per cent. For spaces where average DF is under 2 per cent the supplementary lighting is be needed. [27]. The use of most common overcast sky distribution, (where the luminance at the horizon is one third that at the zenith of the sky) [27], and an insensitivity of DF to building orientation and sun availability are considered to be a big drawbacks of daylight factor approach. The sunlight strategies based on solar angle or solar intensity have no influence on the DF. Therefore, other indicators of daylight performance and simulations methods are introduced. One of the most discussed ones is climate based daylight modelling (CBDM).
Climate Based Daylight Modelling CBDM Also: http://climate-based-daylighting.com/doku.php?id =academic:climate-based-daylight-modelling	*CBDM is the prediction of various radiant or luminous quantities (e.g. irradiance, illuminance, radiance and luminance) using sun and sky conditions that are derived from standard meteorological datasets. Climate-based modelling delivers predictions of absolute quantities (e.g. illuminance) that are dependent both on the locale (i.e. geographically-specific climate data is used) and the building orientation (i.e. the illumination effect of the sun and non-overcast sky conditions are included), in addition to the building's composition and configuration* [18,28]. Although, the foundations for CBDM were developed in the late 1990 [29], a widely recognition of this method came later on. The UK Education Funding Agency (EFA) The decision to include CBDM evaluation a mandatory requirement and put UDI target levels into their recommendations for British schools seems to be a first step to introduce new dynamic daylight metrics into daylight regulations, in which DF was dominating for many years. The critical voice focuses on complexity of CBDM methods in comparison to DF. The critics also point out the inadequacy of daylight metrics restricted to a horizontal surface compare to a 'daylit' room appearance and the daylight comfort of the user, the unreliability of computer simulations or the hardship of learning software like *Radiance.*
Daylight Autonomy DA (2005)	It is represented as a percentage of annual daytime hours (how often) that a given point in a space is above a specified illumination level-500lx. It was originally proposed by the Association Suisse des Electriciens in 1989 and was improved by Christoph Reinhart between years 2001 and 2004. The limitations are: *DF fails to give significance to those daylight illuminances that are below the threshold. DA makes no account of the amount by which the threshold illuminance was exceeded* [30]. Therefore, there is no information about thermal discomfort of glare [23].

[†] The experiment focusing on daylight indicators in a context of a real urban residential environment is a part of the ongoing PhD research.

Table 2. continue

Useful Daylight Illuminance UDI (2005)	UDI is a modification of Daylight Autonomy suggested by Mardaljevic and Nabil in 2005. [31, 32, 33]. *UDI is defined as the annual occurrence of illuminances across the work plane that are within a range considered "useful" by occupants* [18]. In the first papers published *UDI scheme had 100 and 2000 lux as the lower and upper bounds for useful daylight illuminance achieved*. The 2000 lux value was revised upwards to 3000 lux. *The UDI scheme is applied by determining at each calculation point the occurrence of daylight levels where:* • *The illuminance is less than 100 lux, i.e. UDI 'fell-short' (or UDI-f).* • *The illuminance is greater than 100 lux and less than 300 lux, i.e. UDI supplementary (or UDI-s).* • *The illuminance is greater than 300 lux and less than 3,000 lux, i.e. UDI autonomous (or UDI-a).* *The illuminance is greater than 3,000 lux, i.e. UDI exceeded (or UDI-e)* [28].
Annual Light Exposure	Annual Light Exposure is a performance indicator defined as the cumulative amount of visible light incident on a point of interest over the course of the year. It is used to design spaces that contain light-sensitive artwork. Annual Light Exposure is expressed in lux per year [30].
Annual Sunlight Exposure ASE or aSE (ASE1000lx,250h) Metrics introduced by Illuminating Engineering Society (IES) Daylight Metrics Committee Included in the LEEDv4 daylighting compliance requirements (2013) IES LM-83, aSE	Annual Sunlight Exposure describes the number of hours per year at a given point were direct sun is incident on the surface. In other words, how much of space receives too much direct sunlight, which can cause visual discomfort (glare) or increase cooling loads. Specifically, ASE measures the percentage of floor area that receives at least 1000 lux for at least 250 occupied hours per year. ASE incorporates potential issues of thermal discomfort but it does not address issues of glare and veiling reflections. LEEDv4- Annual Sunlight Exposure (ASE1000lx250h) below 10% in all regularly occupied floor areas. IES, 2014. Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE).
Spatial Daylight Autonomy sDA Metrics introduced by Illuminating Engineering Society (IES) Daylight Metrics Committee IES LM-83	sDA is the percentage of area that is above 300 lx 50% of the time or more during the working hours. LEEDv4 goal is to Achieve a Spatial Daylight Autonomy (sDA300lx,50%) in 55% (2pts) or 75% (3pts). IES, 2014. Approved Method: IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)
Daylight Glare Probability DGP	DGP is a metric to predict the appearance of discomfort glare in daylight spaces, metric calculated at the eye point, proposed in 2005 by Jan Wienold and Jens Christoffersen [34,35,36].

4. Method – pilot study

The most apparent barriers to implementation of daylight design within urban planning in Poland derived from literature are:

- inconsistency in urban residential plans,
- deficiencies in residential stock and rising land prices that mainly drive new residential developments,
- residential design prioritizes quick delivery & profit, not residential comfort,
- daylight design is not seen as a factor contributing to better living conditions,
- lack of national daylight standards and guidelines,
- very limited daylight guidelines in building regulations,
- lack of national initiatives towards promoting daylight design as a sustainable design approach,
- low quality of design solutions as an effect of gaps in education (lighting courses are offered in electrical engineering faculties),
- low awareness of daylight dynamic metrics and assessment methods among architects and urban planners.

4.1. Pilot study overview

To evaluate the findings gathered from available literature a pilot study was carried out as a survey using two questionnaires. A first questionnaire was given to 54 students with backgrounds in architecture (46), interior design (5) and other design areas (3). The students were asked to evaluate the daylight conditions within two chosen classrooms (24 of 54 responders) and in the private rooms they were occupying at the time of the study (30 of 54 respondents). During the assessment, general questions concerning students' acquaintance with daylight were asked.

Additionally, a second questionnaire regarding daylight regulation was distributed among 28 other architecture students. All the participants (54+28) in the survey had passed lighting classes required by their curricula.

4.2. Selected pilot study results

The first questionnaire illustrated that expectations of daylight are similar in school and residential environments. Although, the view out was a more important factor for students who assessed their own living spaces. Only eight out of the group of 30 respondents were dissatisfied with the lighting schemes in their dwellings. Eighteen of the 24 students evaluating classrooms were dissatisfied with the view out. These respondents pointed out a lack of interesting views out, daylight glare and a lack of daylight control as the main factors contributing to their dissatisfaction with lighting. Eight-five respondents believed that combining electric lighting schemes with daylight design would contribute to energy savings and improve the quality of space. The results demonstrate that more information about daylight design is needed, especially in the area of energy savings potential, and that combinations of daylight schemes with electric ones would be welcomed. Respectively, half of the questioned students would like to be introduced to daylight design methods and calculation techniques. However, only 31% of the whole tested group would welcome daylight regulations. Results of the second questionnaire proved that although there is an awareness of daylight, but there is also a general lack of knowledge on this subject. Among 28 students showed that 32% of them could not name any daylight regulation. Other 32% of students had the brief knowledge that daylight was mentioned in Polish building standards. The majority of respondents could not indicate any example of the implementation of good daylight strategies in architectural planning.

5. Conclusions

Undoubtedly, the role of daylight design in creating sustainable and comfortable environment is growing. Daylight can be a driving force for reshaping the way modern cities are created, but modern daylight design methods have to be introduced in practice and regulatory documents. Current Polish building standards containing daylight recommendations do not precisely indicate what actions are required to provide good daylight design and what kind of daylight metrics are needed to achieve a better quality of daylight. The answer to a question how to describe daylight is still not clear. The large number of studies and research papers written in the field of daylight dynamic metrics suggests that those metrics may be seen as a set of new tools to create well day-lit spaces that satisfy occupants' health and comfort needs, and offer stimulating and energy-efficient architectural solutions. However, big disadvantages of these methods are their quantity and complexity. The biggest challenge for an incorporation of modern daylight evaluation methods into urban planning is to overcome barriers, to simplify and introduce them to architects and urban designers. The results of the pilot questionnaire show a lack of daylight training among future architects and urban specialists. Therefore, new educational channels should be created to propagate the use of daylight design methods and techniques amongst professionals engaged in urban planning processes.

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