 doi:10.20944/preprints201711.0174.v2

Article

Daytime Lighting Assessment in Textile Factory Using Connected Windows in Slovakia; Case Study

Dušan Katunský[1,*], Erika Dolníková[2] and Bystrík Dolník[3]

[1] Department of Architecture and Building Structures, Institute of Architectural Engineering, Faculty of Civil Engineering, , Technical University of Kosice, Slovak Republic
[2] Department of Building Physics, Institute of Architectural Engineering, Faculty of Civil Engineering, Technical University of Kosice, Slovak Republic
[3] Department of Electric Power Engineering, Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Slovak Republic
* Correspondence: dusan.katunsky@tuke.sk ; Tel.: +421-055-602-4157

Abstract: The paper highlights the problems associated with daylight use in industrial facilities. In a case study of a multi-story textile factory, we report how to evaluate daylighting (as part of integral light) in production halls marked F and G. The post follows the article in the Buildings journal, where Hall E was evaluated (unilateral daylight). These two additional halls have large areas of 54 x 54 meters and are more than 5 meters high. The daylight is only on the side through the attached windows in envelope structures in the vertical position. In this paper we want to present two case studies of these two production halls in a textile factory in eastern part of Slovakia. These are halls that are illuminated by daylight from two sides through exterior peripheral walls that are against or next to each other. The results of case studies can be applied in similar production halls illuminated by a "double-sided" double (bilateral) daylight system. This means that they are illuminated by natural illumination through windows on two sides in a vertical position. Such a situation is typical for multi-storey buildings in industry. The proposed approximate calculation method for daylight factor can be used to predict daylight in similar spaces in other similar buildings.

Keywords: sustainable architecture; industrial building; indoor environment; lighting conditions; computational simulation; luminance

---

1. Introduction

Many authors deal with daylight systems. An active solar daylighting system behind the perimeter wall is described by (Kontadakis,A. et al. [1]). Also (Tsangrassoulis,A. et al. [2]) deals with the prototype of the hybrid daylight system. Some other aspects play an important role for daylight, such as dimming in relation to daylight (Doulos,L. et al. [3]). Author (Doulos, L., et al. [4]) also describes the role of spectral response of photosensors in daylight response systems. One of the well-known author dealing with daylighting and its impact on building users is (Belia, L. [5, 6]).

The influence of daylight during daytime on human health was studied by the authors (Shishegar,N. et al. [7]) and (Friborg,O. et al. [8]). Daylight affects the physiological and biological processes in the human body (McColl,S.L. et al. [9]), (Smolders,K.C. et al. [10]), as well as the visual perception of interior interiors (Yao, J. et al. [11]) and (Fabi,V. et al. [12]). Gou studied visual comfort and light simulated effects in relation to workers' productivity and well-being (Gou,Z. et al. [13,14]). The authors are directing research into the performance of people in the building in terms of daily and artificial lighting of the indoor environment. Research on nonvisual daytime light effects on humans in buildings, for non-visual health potential, visual interest and observed behavior is found in works (Amundadottir,M.L. et al. [15]) and visual perception describes (Lee,J.H. et al. [16]). Direct sunlight and its effects are investigated by (Wang, N. et al. [17]), (Yokoya,M. et al. [18]), (Lee,K.S. et al. [19]). A barrier to dazzle and unpleasant dazzling is described (Hirning,M.B. et al. [20,21]). Shen monitors model containing a synchronized daylight shadow operation with simplified control (Shen,H. & Tzempelikos,A. [22]). Research in this field is also focused on different types of microclimates, as well as on an overall assessment of the internal environment, (Švajlenka, J. et al. [23,24]).

Several objectives have been directed towards scientific research in the field of design, use and assessment of buildings in industry. another objective was to assess the energy consumption for heating of production buildings considering the effect of different zones on total energy consumption (Bawaneh,K.et al.[25]). Various HVAC systems in relation to the reduction of energy consumption in buildings were analyzed (Zhivov, A.M. et al. [26]). The need for thermal energy in the industrial hall to save the total consumption of heat energy for the heating of the production building (Katunský,D. et al. [27]). The impact of transparent structures on the heat energy consumption of industrial halls to I mprove the design of energy saving windows has been analyzed (Wang,H. W. et al. [28]).

In terms of indoor lighting, various types of buildings requiring demanding visual activities are examined in the literature. Educational buildings and schools are dealt with by (Ferencikova, M. & Darula,S. [29]), (Moazzeni,M.H. et al. [30]), (Kruger, E.L. et al. [31]), (Piderit Moreno,M.B. et al. [32]) and others. Residential buildings are followed by (Xue,P. et al. [33]), (Nebia,B. et al. [34]), apartment buildings by (Iringova,A. et al. [35]), atrium building by (Mohsenin, M. et al. [36]), (Berrardi,U. et al. [37]), (Gonzales,J. et al. [38]), (Pellegrino,A. et al. [39]), (Costanzo,V. et al. [40]) and (Konis, K. [41]).

Different types of light or lighting are the sum of the research activities of the team (Mistrick, R. et al. [42]), which deals with computer modeling of photocontrols of electric lighting systems integrated daily. Simulation and modeling of daylight is monitored by (Nasrollahi,N. et al. [43]). The energy efficiency of light is monitored by (Reinhart,C.F. et al. [44]). The use of daylight when confronted with cold LED illumination is described by (Amorim,R. et al. [45]), the energy and visual control of (Shen,E. et al. [46]), the lateral and visible atmosphere of (Uriarte,U. et al. [47]). Adaptive light is tracked by (Gunay,H.B. et al. [48]) and a simulation to visualize and debug the behavior of the lighting regulator (Jia,L. et al.) [49]. An analysis of several criteria for selecting the optimal position and the correct field of view of the photosensor in a building is required and also the quantification of energy savings in daylight response systems in the dimming function of electronic ballasts (Doulos,L. et al. [50,51]). Chromaticity-matched but spectrally different light effects source on simple and complex color judgments is by (Veitch,J.A. et al. [52]). The meteorological models of the distribution of the brightness of the sky of external lighting and the approximate configuration and validation of the sky were studied by (Perez,R. [53] and Igawa,N. [54]).

As a result, daylighting is very important in industrial halls for visual convenience. For human visual and circadian rhythms, this is very important and effectively stimulates them. Unless we take into account all the needs and benefits, daylight can affect visual performance; it can cause discomfort by dazzling eyes and unpleasant scatteriness in the interior. Daylight may also weaken performance by creating shadows in the workplace. The effectiveness of electrical, artificial lighting in daylight depends on the quality of light sources, similar to radiation as daylight. Therefore, the negative aspects are also positive in the daylight. Integral lighting dealt with and proposed certain conditions of use (Katunský D. et al.) [55]. Lighting conditions at workplaces were examined using both practical and calculation methods. (Van Bommel,W.J.M. & van den Beld,G.J. [56]). Influence of user behavior on unsatisfactory indoor thermal environment is described by (Yan,B. et al. [57]).

Incorporation of methods of daylight assessment into urbanization was studied by (Sokol,N. & Martyniuk-Peczek,J. [58]) and (Chen,K.W. & Norford, L. [59]). These comments motivated us to carry out the current research focusing on lighting systems to improve the internal quality of the environment and workers' comfort while reducing overall energy consumption (Labat,M. & Attonaty,K.) [60], (Gourlis,G. & Ivacic,I.) [61], (Pham,K. et al.) [62].

One of the first to focus on the assessment of the impact of industrial buildings on the environment in terms of their sustainability is (Alarcon, B. et al., [63]). The effectiveness of lighting in an industrial factory, case study in Slovakia was examined by (Katunský,D. et al. [64]). New models for sustainability assessment criteria in industrial buildings have been developed (Lombera, J.T. & Rojo, J.C. [65]). The modified criteria for assessment of industrial buildings' sustainability have resulted in the development of new models (Lombera, J.T. & Aprea, I.G. [66]). In this text, the authors want to outline the continuation of the research.

2. Aim of the research

In design of construction and operation of manufacturing buildings is it necessary to consider the requirements for the sustainability of buildings. Especially we are interested in the microclimate in the interiors of buildings in the industry focusing on indoor microclimate light, thermal humidity and others with an emphasis on energy saving in operation. Last but not least, it is the area of building sustainability.

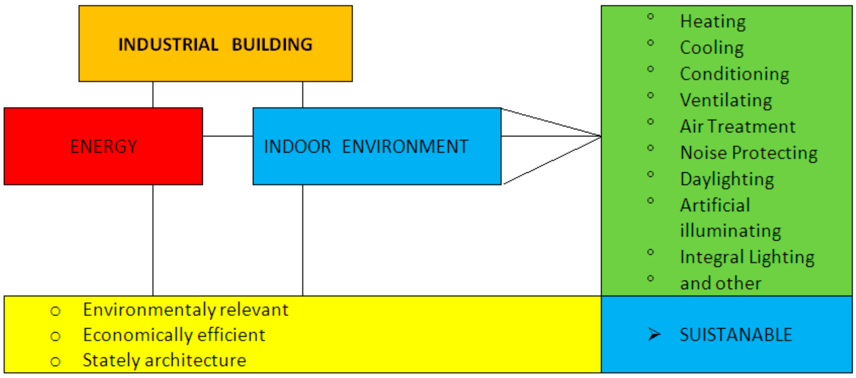


Figure 1. Creation of an industrial building and requirements for indoor environment

An industrial building must be environmentally relevant, economically efficient, with stately architecture so that it leads to sustainability even in industry (see Figure 1). In this paper, we are primarily concerned to daytime lighting by window constructions in industry and indoor environment lihgting conditions in industrial building.

2.1. Methodology

In this article, we take into account daytime lighting in an industrial factory (textile factory) – case study, outside the city where one hall is above the other, one interior is above the other and there is no shading. Production halls are referred to as A, B, C, D... We are only interested in one part of the indoor environment - lighting. It is not possible to meet daylight requirement for visibility at remote locations with daytime lighting unilateral lighting (one side), as shown in [64], where the hall is marked as "E". The case study in this document points out how it is with illumination from two parties (ie bilaterally) in the "F" and "G" halls.

If we can not meet the requirements for daylight there must be a combination of daylight and artificial lighting, i.g. integral or integrated lighting. The task is to determine the methodology for determining the minimum required DF factors for integral lighting, as prescribed in the Czech Standard. The research was carried out in textile halls in town located in eastern part of Slovakia. In this work, we present two knitted factories in the textile factory, which differ in the location of the windows. The predominant role of this research was to analyze the impact of window placement on daylight industrial hall lighting with regard to integrated dynamic simulations and real in situ measurement methods. The on-going view offers an analysis of daylight conditions that also use measurement in situ and dynamic simulation, leading to design windows and optimization of sustainability monitoring.

This work is a continuation of the comprehensive research of the quality of the internal working environment of the conditions (internal microenvironments) of industrial buildings. Previously, we

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

investigated the microclimates of the heat humidity and the energy required to heat the production hall by means of measurements and dynamic simulations.

2.2. Daylighting according to Czech and Slovak standards

In the recent past, a number of technical lighting standards have changed, which deal with natural daylight and artificial illumination. Associated lighting is addressed in many standards as part of the artificial lighting regulations. The Standard for Building Integral Lighting was valid in the Czech Republic also after the revision. In standards Daylight Factor DF% is is considered and determined for the assessment of the indoor daylight environment. Equation 1 can be used to calculate by the cloudy sky with a uniform cloud.

$$DF = \frac{Internal\ illuminance}{External\ illuminance} 100\ \% \quad (1)$$

Prescription of DF according to a Slovak standard can be seen in Figure 2. The rule of minimum and average DF daylight factor for all seven light-technical recognition categories according to the Slovak national standard can be seen in Figure 2.

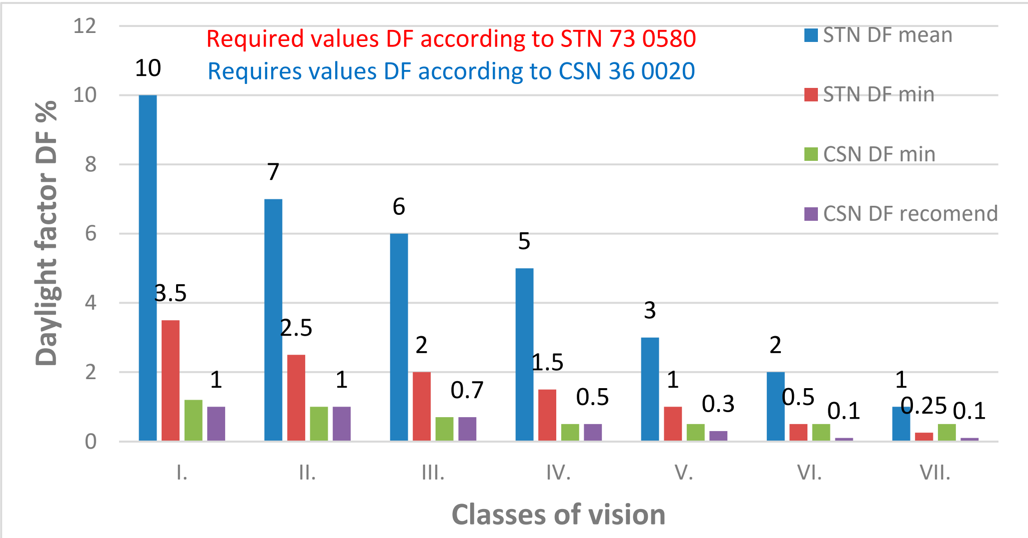


Figure 2. Comparison of DF prescribtion according to Czech standard CSN 36 00 20 [67] and Slovak standard STN 730580 [68]

Classification of the internal daylighting indoor-environment according to Slovak technical standards is based on the work, its complexity and the basic requirements that are placed on the complexity of the visual activity.

Artifficial lighting is determined with EN 12464-1 2011 "Light and lighting — Lighting of work places, Part 1 Indoor work places" for "night time conditions" only [69]. Namely, the corresponding light levels from artificial lighting system are calculated without the influence of daylight. Thus the only combination of daylight and artificial should be with the use of photosensors.

In Czech standard "Integral lighting in buildings" [67], interiors are classified into seven groups according to the intensity of visual activities performed inside a building. Similarly, in the Slovak standard [68], values of DF are grouped into seven categories representing human eye recognition for visual detail tasks. The main starting point for determining the requirements at the level of combined lighting is the classification of visual activities performed in a building according to [67], [68] (Fig. 2).

Table 1. Classification of human eye recognition of visual detail tasks according to the Slovak national standard STN 730580 [68].

Human eye recognition category		Visual detail tasks
I.	Extreme accuracy	The most accurate visual work with limited use of magnification, with the requirement to eliminate errors in definition, stringent control
II.	High accuracy	Very precise production and control activities, high-precision drawing, hand engraving with very small detailing, fine art work
III.	Precise operation	Precision manufacturing and inspection, regular drawing, technical drawing, consuming laboratory, labor-intensive investigations, fine sewing, embroidery
IV.	Medium accuracy	Medium precision manufacturing and inspection, reading, writing (by hand and machine), routine laboratory work, examinations, treatments, using machines, thicker sewing, knitting, laundry, cooking class, reading room, teaching cabinet, kitchen, doctor's surgery, office, meeting room, conference room
V.	Low accuracy	Approximate works, manipulating objects and materials, food consumption and service, leisure activities, physical education, dining room, living room, lounge, hall, gymnasium, swimming pool, storage room, waiting room
VI.	Very rough work	Maintenance cleaning, showering and washing, changing, walking on public roads open to the public, cloakroom, toilets, corridors
VII.	Only spatial orientation	Walking, material transport, storage of raw material, supervision

The norm is the classification of classes I through VII according to the intensity of the visual action (Table 1 and Figure 2). The same classification applies to daily STNs and the same for CSN integral lighting. The same applies to the relative observation distance. The difference is in the prescribed minimum DF factors (see Figure 2) as well as differences in permitted brightness. One important step is to evaluate the light contrast.

Problems related to industrial buildings have not been thoroughly reviewed until such details as another type of buildings. The criteria for residential and civil non-production buildings do not apply to industrial buildings. Therefore, it is necessary to make certain changes in the methods and approaches to assessing the design of buildings in the industrial sectors.

2.3. Daylighting according to European standard

In the draft of the European standard, the rules are slightly different from national standards. Other factors are taken into account here. This standard evaluates permanently inhabited areas, classifies buildings' premises according to function and work activities, and defines areas with day lighting requirements. The daylight assessment features are applied mainly to industrial areas, office, civic, school, health, business and apartment buildings, prisons and care homes. Daylight availability is determined by the median of horizontal diffuse illumination at location Emed. Daylight is intended to provide levels of natural light higher than critical visual daylight lighting level of 300 lx. Daily lighting requirements should be adequate, with an acceptable minimum of 100 lux. Target factor D_T is the daily lighting factor to be achieved in a certain portion of an area in order to meet the daylighting criterion. On the working plane, the illumination level is 300 lx. Daylighting factor D_{TM} is the minimum daylight target factor. This is the minimum DF value in a specific location that corresponds to the illuminance level of 100 lx (see Tables 2, 3):

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

Table 2. The maximum permissible brightness (luminance) of the subject observed and the brightness of the illuminating opening positioned 60° from the normal viewing direction according EU standard

Class of visual activities	The ratio of the luminance of the observed object to the luminance of the illuminating opening (windows)
I,II,III	1 : 40
IV	1 : 100
V,VI,VII	not intended

Note: The usual direction of view is a view of the subject of work or other view related to the activity and the relaxation view in the horizontal direction.

Table 3. Recommendation of daylight provision by daylight openings in vertical and inclined surfaces [70]

Level of recommendation for vertical and inclined daylight opening	Target illuminance E_T (lx)	Fraction of space for target level F_{plane},%	Minimum target illuminance E_{TM} (lx)	Fraction of space for Min target level F_{plane},%	Fraction of daylight hours F_{time},%
Minimum	300	50%	100	95%	50%
Medium	500	50%	300	95%	50%
High	750	50%	500	95%	50%

NOTE: Table A.3 in [70] states the target daylight factor (D_T) and the minimum target daylight factor (D_{TM}) corresponding to the target illuminance level and the minimum target illuminance, respectively, for the European CEN capital cities.

Table 4. Assessment of the view outwards from a given position [70]

	Parameter a)		
Level of recommendation for view-out	**Horizontal sight angle**	**Outside distance of the view**	**Number of layers to be seen from at least 75% of utilized area:** **- sky** **- landscape (urban and/or nature)** **- ground**
Minimum	≥ 14°	≥ 6.0 m	At least the landscape layer is included
Medium	≥ 28°	≥ 20.0 m	Landscape layer and one additional layer are included in the same view opening
High	≥ 54°	≥ 50.0 m	all layers are included in the same view opening

a) For a space with room depth of more than 4 m, it is recommended that the respective sum of the view opening(s) dimensions is at least 1.0 m x 1.25m (width x height).

In draft of EU standard shows values of DF for daylight openings to exceed an illuminance level of 100, 300, 500 or 750 lx for a fraction of daylight hours F_{time},% = 50 % for 33 capitals of CEN national members, and values of DF only for horizontal daylight openings with diffusing material 1) to exceed an illuminance level of 100, 300, 500 or 750 lx for a fraction of daylight hours F_{time},% = 50% for 33 capital cities of CEN national members [70].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

3. Case study – textile factory

The research in this case study is a textile factory located in the eastern part of the Slovak Republic in which knitting halls were observed. It is a three-storey steel-skeleton building surrounded by a lightweight cladding and connected windows (window strip).

There are a lot of spaces in this race called A, B, C, D… In article [64], we considered Hall E and in this post we evaluate two halls, Hall F and hall G, which are illuminated by daylight from two sides.

a) Situation of case study b) Bilateral daylight system c) Luminance Internal view

Figure 3. The situation of a textile factory placement, lighting simulation results near windows in double-side window day illumination

Figure 3 shows the view of the building from the outside and the internal view as a result of daylight simulation with the Radiance simulation program.

In this article, we want to show case studies of similar industrial factories that are illuminated by a double-sided daylight system - a strip of windows:

Windows are next to each other in neighboring perimeter walls. (Hall F)

Windows are in perimeter walls against each other. (Hall G)

In these halls was realised:

1) measurement of daylight value,
2) determination of the marginal conditions for the calculation od DF,
3) calculated and simulated daylight situations using the simulation program,
4) confrontation of measured and calculated DF values,
5) derived simplified formula for window design depending on floor area to determine minimum DF (for integral lighting as a basis).

3.1. Daylight measurements

Daylight measurements were performed according to slovak standard "Measurement of daylighting". The measuring instruments were borrowed from the STU Faculty of Civil Engineering in Bratislava. Used “Hagner EC 1 type” two luxmeters, production numbers 5532 and 5531, “Hagner Universal Photometer type S2, S22065”, accuracy 5%, and “Hagner Reference calibration sample” with factor value and a reflection of 0.966. When using a daylight system (according to Slovak valid standard STN 73 0580-1), the minimum standard value DF_{min} = 1.5-2%, the average normalized value $DF_{average}$ = 5-6%, the uniformity of the illumination is more than 0.2-0.3 for a given visual task. According to standard “Measurement of daylighting”, the change in the brightness of the sky at a given height to sky brightness in zenite is 15 ° 0.3-0.6 and for 45 ° 0.7-0.85 is acceptable (see Fig.5). Daylight measurements were performed for two different days when the artificial lighting system was switched off. Control points during the measurement were from the floor of 850 mm, because the need for visual power is at a given height. Measurement was performed at 81 control points simultaneously with two lux meters. It was measured in nine rows (direction E-W) labeled A, B, C, D, E, F, G, H, I at a distance of 3, 9, 15, 21, 27, 33, 39, 45, 51 m from the edge of the peripheral wall. In the longitudinal direction of the hall, it was also measured in nine rows marked 1, 2, 3, 4, 5, 6, 7, 8, 9 at a distance of 3, 9, 15, 21, 27, 33, 39, 45, 51 m from the peripheral wall edge (Fig. 4, 7).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

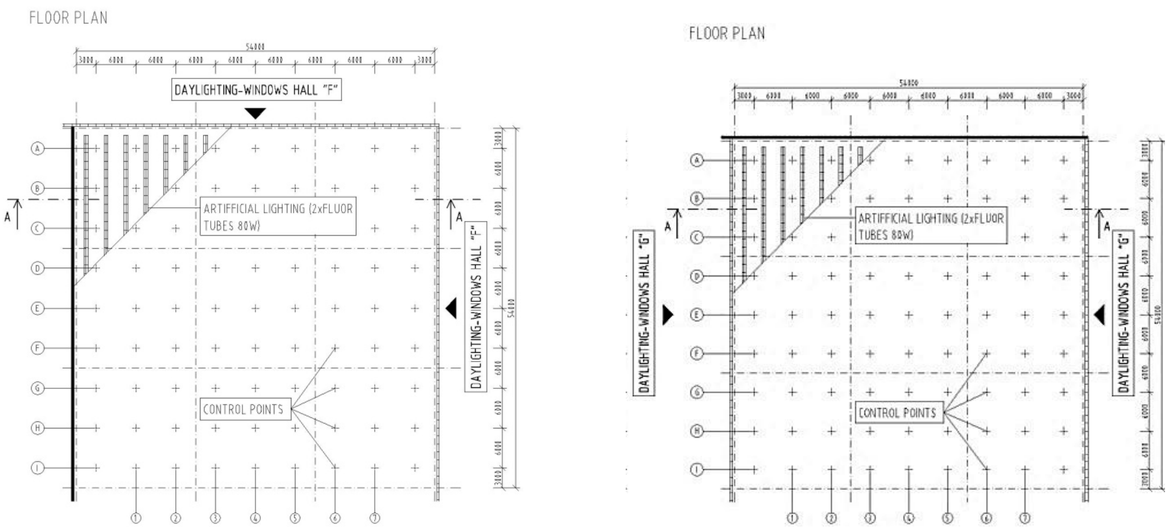


Figure 4. Situation – floorplan of halls F and G

If the device prevents measurement at specified points, it is measured at these points approximately from 30 cm to 50 cm outside the point. One light measuring device measured illumination at a designated location inside the hall; the second light measurement was external, on a horizontal surface (on the roof). Daylight measurements were performed on the first day twice and the other days three times, see Figure 5. At the level of the roof structure, the measurement of the outdoor horizontal illumination, external illuminance (see formula 1) was measured on a non-shielded plane.

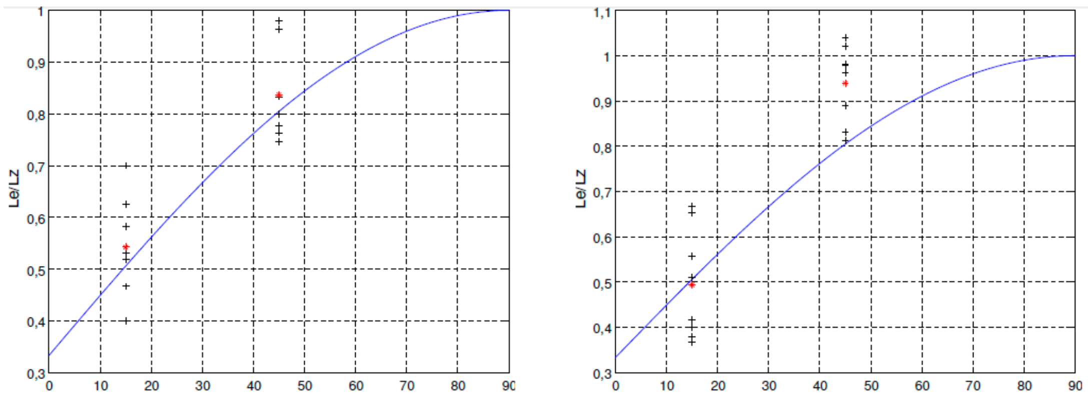
On selected days, the value of the outside light in a cloudy sky ranged from 4,000 lx to 8,000 lx on the first day and the second day from 5,000 lx to 8,000 lx when the measured sky was measured in the direction of the cardinal. Measurement of the brightness distribution in the clouds at the measuring site was performed on both days at the beginning and at the end of the measurement. Comparison of the measured values with the normalized brightness distribution of the evenly cloudy sky on the dark terrain is shown in Figure 5. The final DF values measured at the control points are shown in Fig.6

Daylight measurements were made in December and January in the cloudy sky. The DF values shown in Fig. 6 are calculated from the measurement results as the arithmetic mean of the five measurements. From these data, the DF evaluation parameters that are shown in the figure 6 were calculated. The spatial distribution of DF, the curves of the same brightness curves, and the DF curve decreases with respect to the depth of the space being considered are similar to Figures. 8,9,10 The light reflection factor was determined according standards. Luminance was located according to the wall, ceiling, floor, and interior.

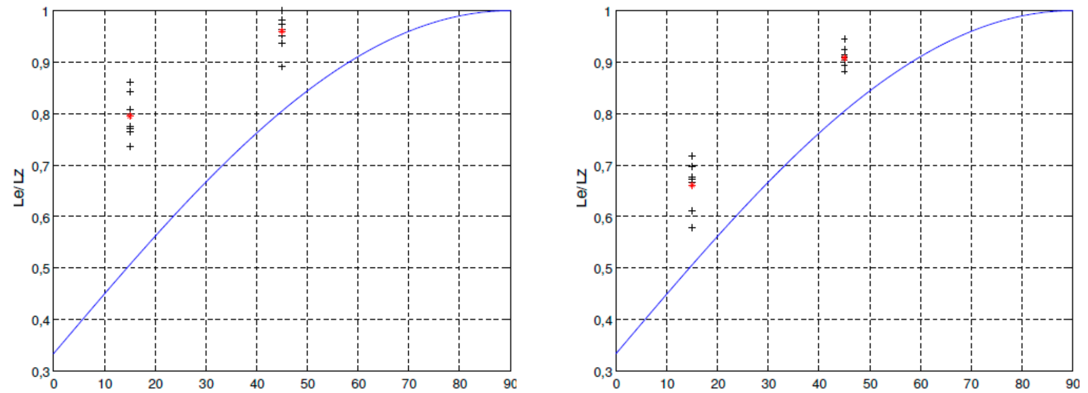
From the measured luminance values of the individual surfaces and the known reflection factor of the calibration sample, the resulting reflection factor of the measured surfaces was calculated. The values of the calculated reflection factors were used as inputs for assigning the properties of the material surfaces in the hall.

From the graphs in Figure 5, we can see that the brightness values of the sky at altitude before and after the measurement were almost within the allowed range. That is, on the first day before the measurement, the values at the level of 15° were 0.4-0.7 and the values 45° 0.75-0.85; measured at 15° 0.35-0.68 and at 45° 0.80-1.05. On the second day, the values were measured at 15° 0.774-0.86 and at 45° 0.89-1.0; measured at 15° 0.61-0.72 and at 45° 0.88-0.92. On the first day at the beginning of the measurement, see Figure 5, the average value of the sky illumination was 15° 0.55 and the height was 45° 0.85; at the end of the measurement see figures 5, 0.5 and 0.92. On the second day of measurement, less favorable values were measured: mean value at start of measurement, see Figure 5, height 15° 0.8 and height 45° 0.95; at the end of the measurement 0.68 and 0.9 (see Fig.5).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2



First day (a) the beginning; and (b) the end of the measurement x - elevation angle, y - ratio Le/Lz



Second day (a) the beginning; and (b) the end of the measurement x - elevation angle, y - ratio Le / Lz

Figure 5. The measured sky conditions rating gradations of brightness sky, x - elevation angle, y - ratio Le / Lz, Le external sky luminance, Lz sky luminance at an angle of Z 15 °and 45 °

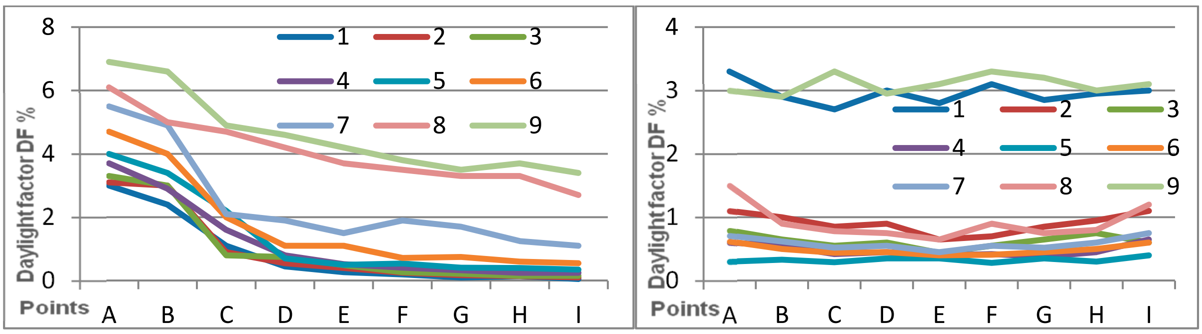


Figure 6. The measured *DF* values in control points in hall F and G

3.2. Daylight calculations

Boundary conditions for calculations have been observed in the measurement of daylighting. The following conditions for calculation were considered:

External illuminance is considered of 5000 lx; (in the draft EU standards is considered for every capital city of 33 EU members other value. For Bratislava (Slovakia) it is 16,300 lx. Height of interior space of hall is 5100 mm. The parapet is at a height 1200 mm. The dimensions of the windows – high of window strip is 2400 mm and the wall thickness were varied for alternatives 100 to 300 mm:

Light loss coefficients, normal light transmittance τglazing = τ1 = 0.92, influence of the frame on light transmittance of windows τ2 = 0.74, the influence of glass cleanliness τ3 = 0.80, influence of interior and shading elements τ4 = 1.0.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

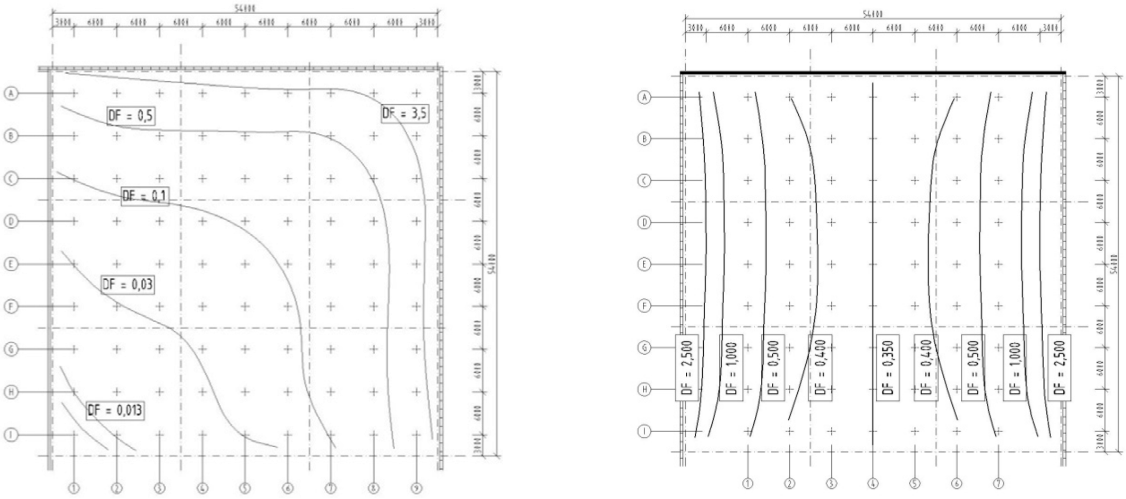
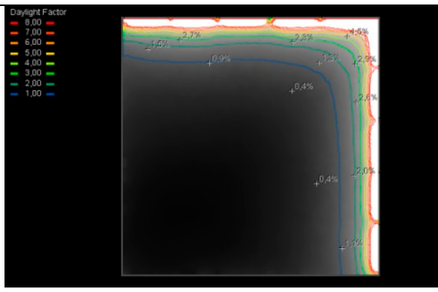
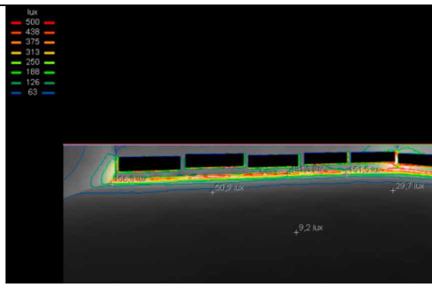
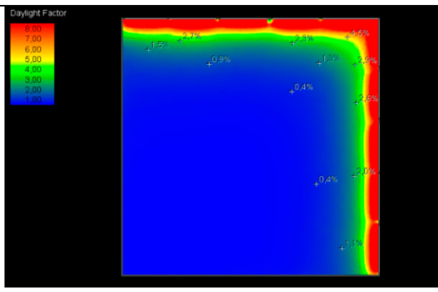
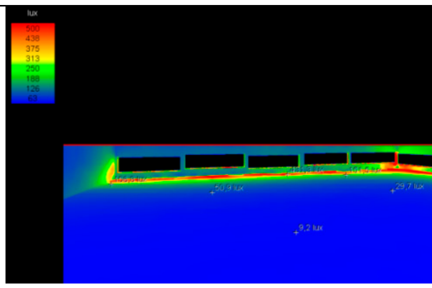


Figure 7. DF in halls F, G bilateral daylight system, the calculated *DF* values

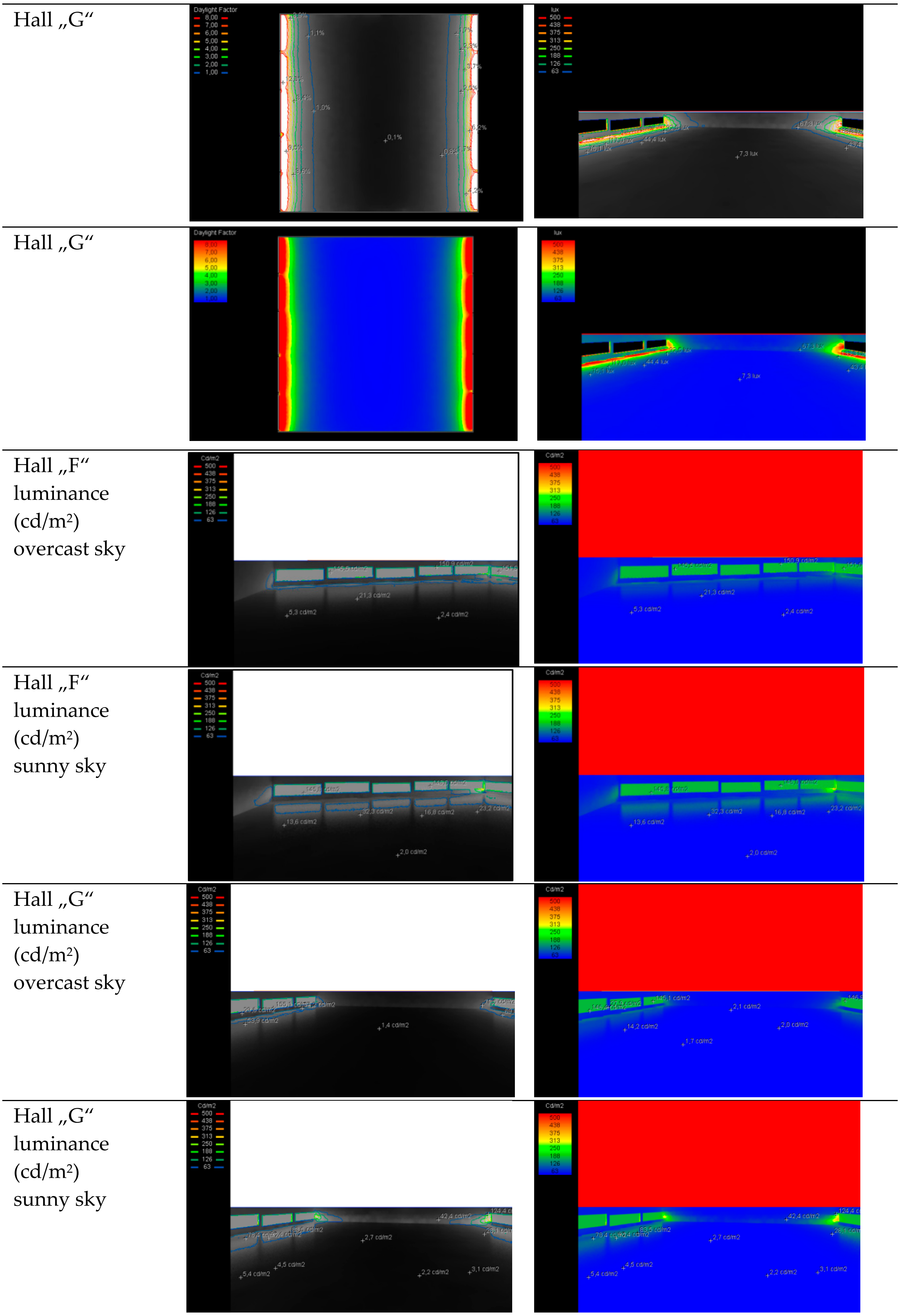
Coefficients of reflections (ϱ) of the light of individual surfaces: white ceiling ϱ = 0.75, glass areas ϱ = 0.10, walls ϱ = 0.70, external terrane ϱ = 0.15 (no snow), light green mop board ϱ = 0.65, light brown floor ϱ = 0.50, façade ϱ = 0.45. Plant is located outside the city, where one hall is above the other, there is no shading. Z = 0.

DF values in hall F (double-sided daylight system of windows next to each other) and Hall G (double-sided daylight system of opposite windows) are measured and computed. Halls reduce the DF due to the depth of the tract.

The results of DF and lighting calculated in the F and G halls and the luminance (cd/m²) in halls F and G calculated without a space device can be seen in Figure 8.

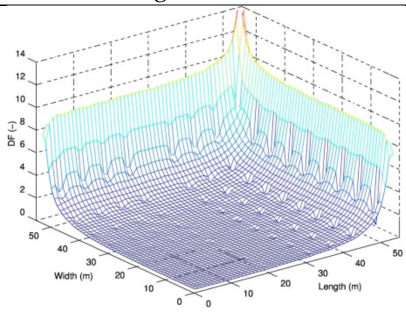
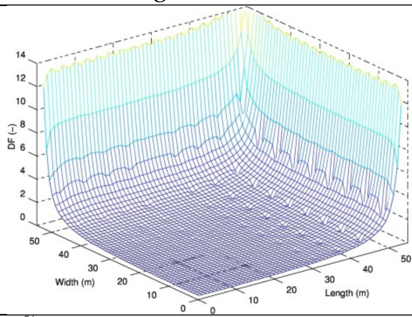
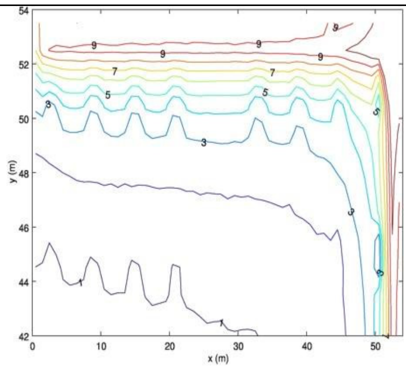
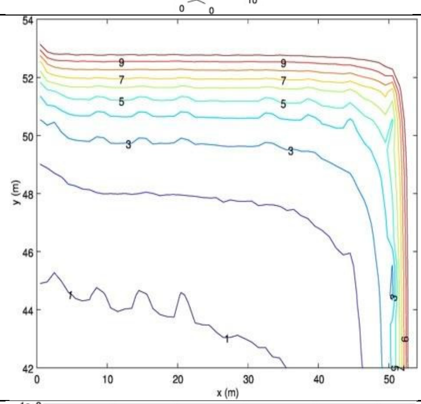
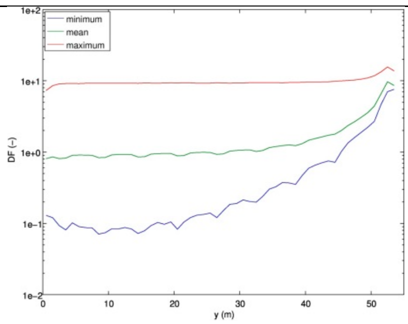
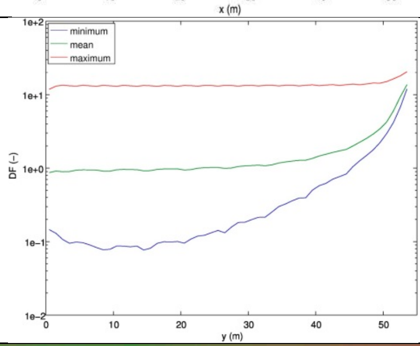
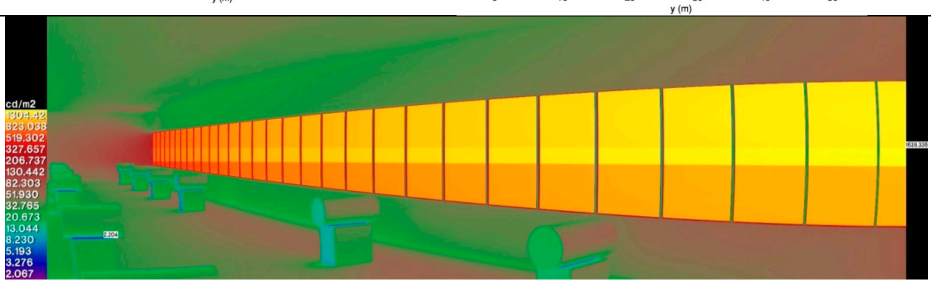
A/ Bilateral daylight	**DF (%)**	**Illumination (lx)**
Hall „F"		
Hall „F"		

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2



301 **Figure 8.** Results of daylight factor *DF* (%), illumination *I (lx)* and luminance (cd/m²) in halls F and G
302 calculated without a space device.

In Hall E, daytime lighting was provided on one side only. The results are similar to those in the F and G halls, except that symmetry is different. In Hall F, the symmetry axis is diagonally across points A9 to I1, in Hall G in the center through points A4 to I4. In Hall F there was no duplication of results in any points, despite the fact that lighting is from two sides. In hall G, daylight factor can be determined by superposition of values. It is the sum of the highest value near the windows and the lowest value at the extreme point. In other points, the results are mirrored. When it comes to simulation programs, it is different. The results depend on the program used and the exact specification of the input data. Some programs also take into account the interior and the production process. In the industry, it is quite difficult to simulate a situation that would correspond to reality. We tried to simulate especially the visual perception of the interior, the observed detail and the view of the windows. The results using simulation programs for the unfinished as well as the furnished interior can be seen in Fig. 9.

	DF (%) Window height 2400, wall 300 mm	DF (%) Window height 2400, wall 100 mm
In space 3D		
In floor plan		
In cross section		
Sunny sky near windows		

doi:10.20944/preprints201711.0174.v2

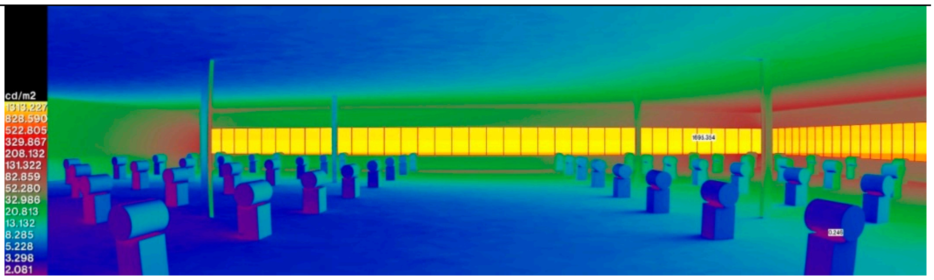
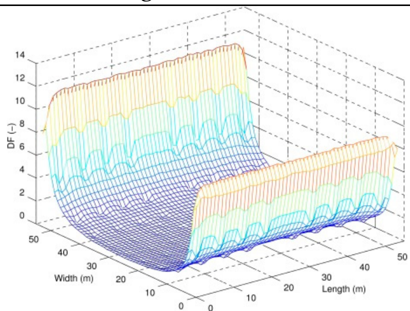
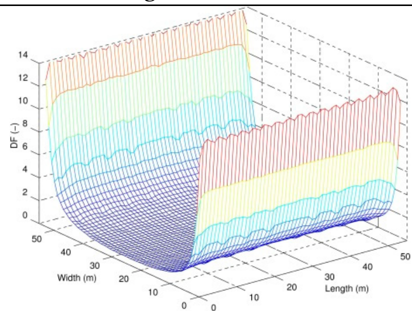
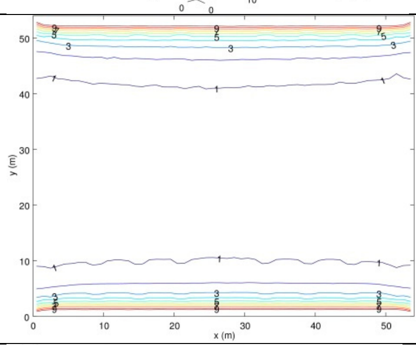
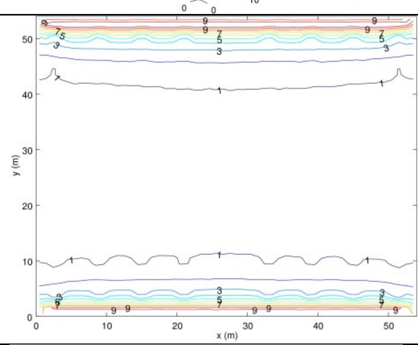
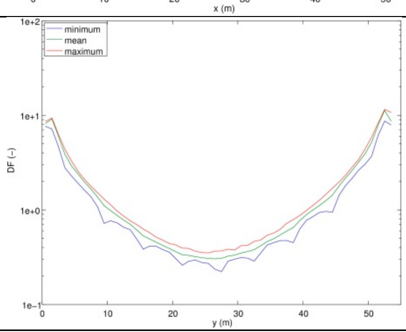
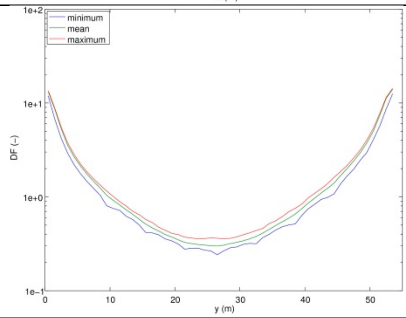
overcast sky overall view	

Figure 9. Results of daylight factor *DF* (%), illumination *I (lx)* in hall F calculated by a simulation programe without a space device, and results of luminance (cd/m²) in hall F with the hall equipment calculated by Radiance – dynamic simulation program.

In figure 10 can be seen the level of DF factor in space (3D), floor plan (2D) and in section (1D) for alternative calculations with wall thickness variations of 300 mm and 100 mm. Figure 10 shows the outputs obtained by the same procedure for Hall G.

	DF (%) Window high 2400, wall 300 mm	DF (%) Window high 2400, wall 100 mm
In space 3D		
In floor plan		
In cross section		

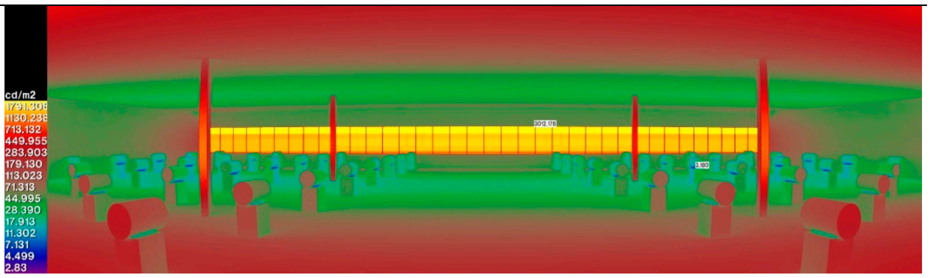
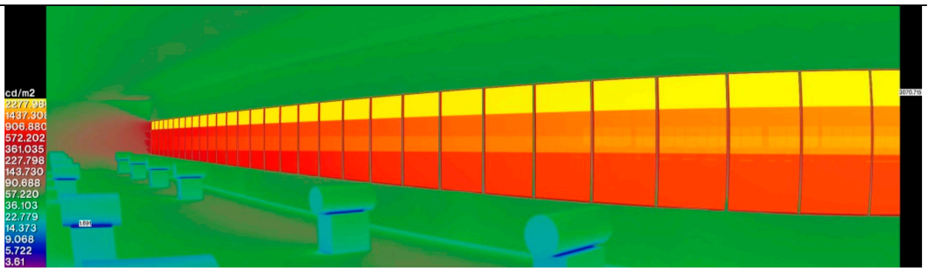
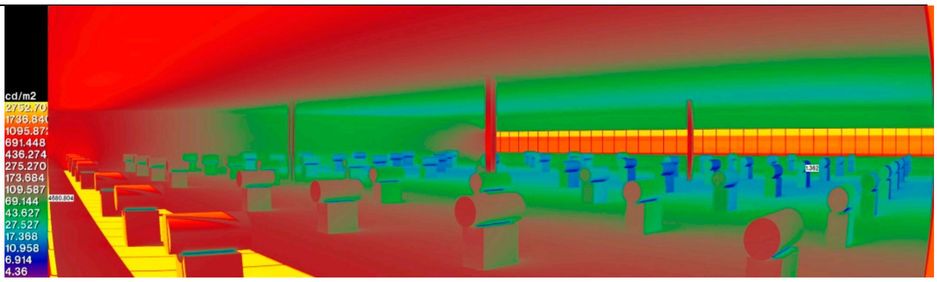
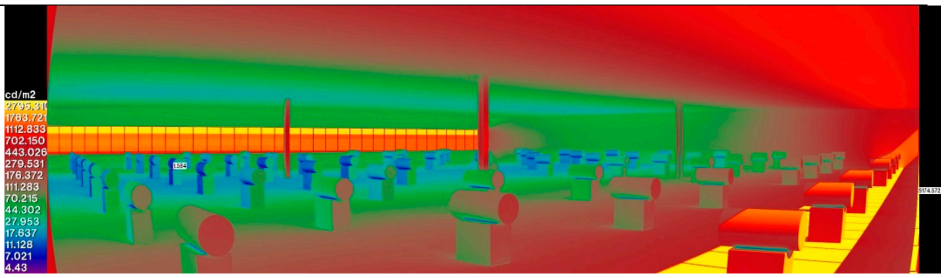
Luminance (cd/m²)	
Luminance (cd/m²) Sunny sky Detailed view	
Luminance (cd/m²) Sunny sky View left side	
Luminance (cd/m²) Sunny sky View right side	

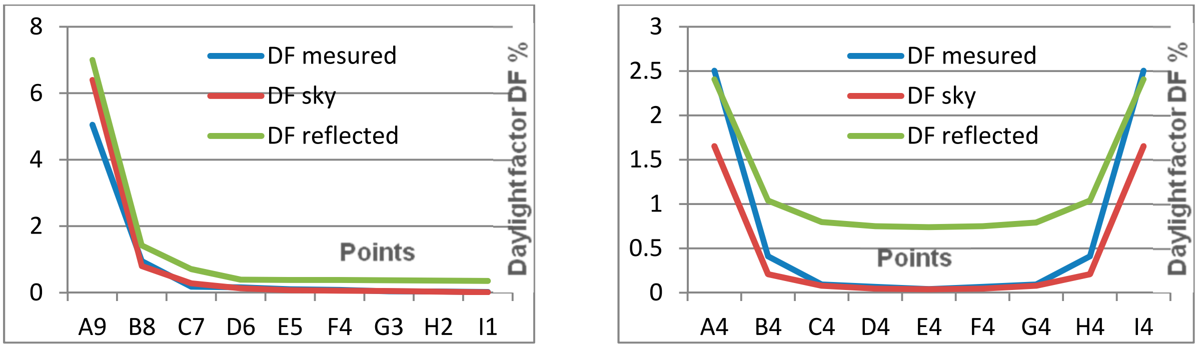
Figure 10. Results of daylight factor *DF* (%) illumination *I (lx)* in hall G calculated by a simulation programe without a space device and results of luminance (cd/m²) in hall G with the hall equipment calculated by the Radiance simulation program.

The calculation that tracks the results for hall G (Figure 7) was done with the same simulation programs as for hall F. This G Hall has a two-sided illumination system with windows facing each other. Alternatively, daylight factor DF (%) for window height of 2400 mm and wall thickness also 300 mm and 100 mm can be seen in the 3D space, in the plan view and in the cut. Interesting is the luminosity in the furnished interior.

4. Evaluation and discussion

The values of the selection characteristics of a set are calculated at each measurement point. In the creation of the hall model, marginal conditions were created based on measurements in the hall. Individual measured material constants (factors of reflection of surfaces, pollution factors and glazing permeability) were considered. The hall model evaluation was performed by a statistical analysis of measured calculated values. The mean error of error between the measured DF values and the DF values calculated by the simulation does not exceed 7% in absolute value. To determine whether the model is overvalued or underestimated, a deviation of +0.67% was calculated, which means that the model is underestimated.

Comparison of the measured daylight values and calculated in Hall F and Hall G was performed diagonally - in the symmetry axis of the inner space, since the same factor DF and daylight isophones were parallel to each other on the outer perimeter walls. DF values were also set for windows with different wall thicknesses (100, 300 mm) for Radiance simulations. When the thickness of the outer wall increased, the DF sky component decreased (see Figures 9,10).



Hall „F“ Hall „G“

Figure 11. Confrontation of the measured, calculated lines of "sky" and "reflected components" of *DF* values in cross section in the midle of working activity (diagonal axis) in hall F and G

In this study, the results of measurements and calculations data for control points are also presented. The results for selected nine control points A4 to I4 in the center of hall "G" and points A9 to I1 in the diagonal axis of hall "F" (see fig. 11).

By comparing the calculated and measured data, we can conclude that the course is similar. As far as the level of daylight is concerned, there are differences. Factor DF has three components (oblique component dash and reflective inner components and reflective outer components that can be calculated as $DF_{reflected}$ (see [64].) In most cases, this is calculated together and has a constant value, the Dw distance based on the above analysis can be used for relations 2 to 4 where the center of the space being considered is the $DF_{reflected}$ diameter as for the factor $DF_{measured}$ in Hall F, where the windows are the same, its measured value is almost twice as high in close proximity to windows as in window G, where the windows are opposite to each other (Figure 11), the lowest DF level at the outermost locations of the windows, and the resulting measured value is closer to the DF sky due to the shielding of the device, and the DF values can also be seen using the calculation program shown in Figure 8.

Changing the level of the reflection component DF at the distance from the daylight opening Dw is expressed by the equation. (2) [64]. The reflected component DF at the distance Dw from the openings fill changes from $D\rho$,min to $D\rho$,max with an average $D\rho$,mean value. This value is the average in the center of the space under consideration. *DF* can be expressed by equation. (3):

$$DF = D_{\rho,mean} K^{\psi} \qquad (2)$$

K and ψ in equation (2) can be calculated using Eqs. (3) (4):

$$K = \frac{D_{\rho,min}}{D_{\rho,mean}} \ (-) \qquad (3)$$

$D_{\rho,max}$ Maximum internal reflected daylight factor %
$D_{\rho,mean}$ Mean (average) internal reflected daylight factor %
$D_{\rho,min}$ Minimum internal reflected daylight factor %

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

$$\psi = \frac{2D_W - T_d}{T_d - 2}\ (-) \qquad (4)$$

D_w Distance from daylight opening m
T_d Distance of the outermost point from the windows in the space considered.

The resulting DF also influences the peripheral wall structures. Figures 6 and 7 have documented the results of DF and illumination for alternative wall thicknesses of 300 mm and 100 mm in the 3D space in the plan view and in the cut. Figure 9 shows the dependence of the wall thickness on the DF at the points of the symmetry axis. For hall F there are points A9 to I1. The influence of the wall thickness on the DF level is that for every 100 mm the DF drops by about 7%.

Daylight and DF were measured in several production halls. This article shows two case studies. When analyzing the proportion of glazed area (windows in the vertical plane) to the floor area, this proportion varies from 3 to 6% in halls with a large floor area.

Based on this analysis, we can in this case also calculate DF relationship, which uses the percentage of glazing P

$$P = \frac{A_W}{A_F}\ (-) \qquad (5)$$

We can express daylight factor as:

$$DF = \left(2.926{D_w}^{-2.115}\right).P^B \qquad (6)$$

where

A_W Area of the window structures m^2
A_F Area of the floor m^2
B can be calculated:

$$B = 1.287 + 0.126D_w - 6.6 \times 10^{-3}{D_w}^2 + 9.8 \times 10^{-5}{D_w}^3 \qquad (7)$$

The DF results, depending on the distance from daylight opening Dw and percentages of the glazing P can also be seen in Figure 12.

The integral lighting of the workplace is implemented as a single system with regard to directionality, shading, glare blocking, contrast of brightness in the field of vision and other requirements specified in the technical standards [68], [69], [70]:

In this study, we reviewed and analyzed the effectiveness and adequacy of daylight that forms the basis for the application of integral light. A case study was conducted in two large industrial buildings to make a picture of the state of the environment and the ability to meet the relevant standards. As mentioned in the accompanying lighting application, there is a prescription - a standard in the Czech Republic that prescribes minimal indoor climate requirements for minimum daylight. Emphasis has therefore been put on the use of daylight to increase the visual comfort of the industrial hall during the day and thus the possibility of saving energy on artificial light. We have noticed that daylighting in the tested knitting hall of a textile factory does not meet the required conditions throughout the work area. The hall has no day and night. The whole is used during the day, where there are pleated machines that serve man. At points and places where the values are lower than the required illumination size, artificial lighting such as electric lights is needed to supplement the daylight to reach the desired levels. The overall situation is particularly interesting in terms of visual perception, i. lighting and luminosity. The luminosity should not be greater so that the ratio between the brightness of the observed detail and the ambient luminance is consistent with that shown in the table. 2. Look at the overall lighting situation in halls F and G in Figure 14.

Additional requirements are as follows

- The minimum required values of DF for the individual types of working activity were determined based on CSN 360020 national standard method for integral lighting (see Fig. 2)
- Integral lighting is used indoors or in their functionally defined areas where the daylighting factors are lower than those required by standard, but at least 1/3 of these values.
- Workplaces in premises with illumination openings where the condition under the first point is not met are considered as workplaces without daylight.
- The combined lighting of workplaces shall be designed so that the luminance ratio (1:40, 1:100) in the field of vision shown in the Table 2 is not exceeded.
- If the luminance of the illumination holes is more than 4000 cd/m^2 up to 60° from the normal view, it is restricted by suitable control devices (e.g. blinds, curtains).

In the study, we found that the inner light microclimate differs greatly from the level in article [64], where we dealt with the level using only the unilateral illumination aperture. In this post in halls F and G (we remembered why they are labeled) enough lighting was achieved in in Hall F (the windows are next to each other), the level needed is nearly half the space (about 27 meters from the windows) in Hall G (windows opposed to each other) the level is sufficient to a distance of about 9 meters from the windows. Then niveau of DF drops sharply.

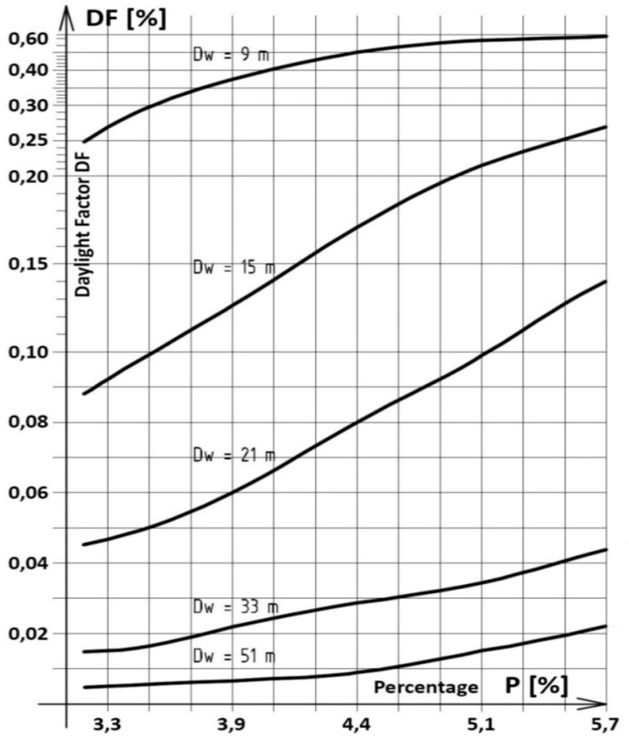


Figure 12. Approximate determination of DF depending on D_w (m) – the distance from the daylight opening and P (%) – the percentage of glazing.

Illumination of hall F is twice as close to the windows as possible from natural lighting than at Hall G. Daily light was measured when artificial light sources were switched off. The measured DF values were found to be the ratios of internal and external illumination (see formula (1).) Luminance and reflection reflection constituents were used in the calculations (in the traditional way) as well as the simulation calculating tools (without the device) and the machine equipment. Even when measured, it can be seen that the machines cause a reduction in the level of daylight by shading at some points. It shows that machines cause some daylight levels to decrease by shading. Based on the above analysis, it can be stated that in very remote places away from windows is not possible to achieve the level of

DF. It would be appropriate to use other ways to get daylight and to distant sites (skylights, reflective surfaces, etc.)

6. Conclusions

The contribution points to assessing visual well-being in large spaces. In this case, it is an industrial operation with ground planes of 54 x 54 metres with a height of about 5 meters. This type of "halls" can also be compared to large-sized spaces in other construction (not only in light industry). Such spaces are also typical of administrative and other buildings in civil construction, where there is a free layout without partitions built in. In this work, the relationship can be applied to predict the size of the glazed parts in the external wall in the given spaces. Since daylight illumination represented by the daylight factor is small, it is necessary to bring distant places into artificial light. For the application of daylight illumination with artificial ones, the physical conditions are not normative. Artificial light always dominates there. Therefore, in absolute terms, we can determine the required value of luminosity in lux, but daylight is suppressed here. As it is known, daylight is at least physiologically and psychologically necessary. A person inside must feel a connection of the enclosed interior with the exterior. This is sometimes only a visual idea that can not be mathematically described, though. Therefore, the need for daylight is small in the conditions we have described. The DF's daylighting factor is of little value. It is prescribed only in some national regulations. When calculating by standard methods, the calculation is based on outdoor lighting of 5000 and 20,000 lx. The new draft of the European Standard is based on the specific conditions of the external lighting of individual countries. It is represented by the outdoor illumination of the capital city.

The calculations we performed and confronted with measurements in a real interior point in a case study of a large-sized interior. It is necessary to emphasize that the results are different if we take into account normative boundary conditions, and are different if we calculate with a simulation program, but in an unadjusted interior, and are yet different if we take into account the prediction of the interior equipment. Any situation of preliminary determination of the layout of the fitting and built-in objects in the interior will be represented by another interior and the calculated results will only be approximate. They will come closer to the values we can expect in a real interior.

The contribution also shows the possibility of approximate determination of DF by glazing. In residential buildings, glazing (windows) is about 10% of the floor area. In industry (mainly light industry buildings) it is about 3 to 6%. For the preliminary determination of the DF, it is possible to use the equation (6) or the graph depicted in Figure 12.

When assessing building sustainability based on computational programs, the daylight element becomes just one of the sustainability assessment indicators. At the same time, the need for daylight is essential for sustainability, and its emphasis should be highlighted in evaluation programs. Of course, it is not a simple matter to find a compromise between ecology, environment, economics and energy requirements. But this is the role of all of us in the future, because getting closer to sustainable development is our goal.

Acknowledgments: This paper was elaborated with financial support of the research project VEGA 1/0674/18 of Scientific Grant Agency, the Ministry of Education, Science, Research, and Sport of the Slovak Republic and the Slovak Academy of Sciences.

Author Contributions: Dušan Katunský coordinated the project, performed the field studies and wrote the initial draft. Erika Dolníková conducted measurements of illuminations. Bystrík Dolník conducted daylight simulations using the simulation computer program. Dušan Katunský, Erika Dolníková and Bystrík Dolník jointly performed analysis of the data and discussed the issues. Dušan Katunský developed the computational model and wrote the final version of the post.

Conflicts of Interest: The authors declare no conflict of interest.

 doi:10.20944/preprints201711.0174.v2

References

1. Kontadakis, A.; Tsangrassoulis, A.; Doulos, L.; Topalis, F. An active sunlight redirection system for daylight enhancement beyond the perimeter zone, *Building and Environment* **2017**, 113,
2. Tsangrassoulis, A.; Doulos, L.; Santamouris, M.; Fontoynont, M.; Maamari, F.; Wilson, M.; Jacobs, A. ; Solomon, J.; Zimmerman, A.; Pohl, W.; Mihalakakou, G. On the energy efficiency of a prototype hybrid daylighting system, *Solar Energy* **2005**, 79, 1
3. Doulos, L.T.; Tsangrassoulis, A.; Kontaxis, P.A.; Kontadakis, A.; Topalis, F.V. Harvesting daylight with LED or T5 fluorescent lamps? The role of dimming, *Energy and Buildings* **2017**, 140
4. Doulos, L.; Tsangrassoulis A.; and Topalis, F. The role of spectral response of photosensors in daylight responsive systems, *Energy and Buildings* **2008**, 40
5. Bellia, L., Fragliasso, F., & Stefanizzi, E. Why are daylight-linked controls (DLCs) not so spread? A literature review. *Building and Environment* **2016**, *106*, 301-312.
6. Bellia, L., Pedace, A., & Fragliasso, F. The impact of the software's choice on dynamic daylight simulations' results: A comparison between daysim and 3ds max design®. *Solar Energy* **2015**, *122*, 249-263.
7. Shishegar, N.; Boubekri, M. Natural light and productivity: Analyzing the impacts of daylighting on students' and workers' health and alertness. In Proceedings of the International Conference on "Health, Biological and Life Science" (HBLS-16), Istanbul, Turkey, 18–19 April **2016**.
8. Friborg, O.; Rosenvinge, J.; Wynn, R.; Gradisar, M. Sleep timing, phonotype, mood, and behavior at an arctic latitude (69°N). *Sleep Med*. **2014**, 15, 798–807.
9. McColl, S. L.; & Wilkinson, F. Visual contrast gain control in migraine: Measures of visual cortical excitability and inhibition. *Cephalalgia* **2000**, *20*(2), 74.
10. Smolders, K.C.H.J.; De Kort, Y.A.W. & Cluitmans, P.J.M. Higher light intensity induces modulations in brain activity even during regular daytime working hours. *Lighting Research and Technology* **2015**, *48*(4), 433-448.
11. Yao, J.; Chow, D.H.C.; Chi, Y.-W. Impact of Manually Controlled Solar Shades on Indoor Visual Comfort. *Sustainability* **2016**, *8*, 727.
12. Fabi, V.; Andersen, R. K.; & Corgnati, S. Verification of stochastic behavioural models of occupants' interactions with windows in residential buildings. *Building and Environment* **2015**, *94*(P1), 371-383.
13. Gou, Z.; Lau, S.S.; Ye, H. Visual alliesthesia: The gap between comfortable and stimulating illuminance settings. *Build. Environ*. **2014**, 82, 42–49.
14. Gou, Z.; Lau, S.S.; Qian, F. Comparison of mood and task performance in naturally-lit and artificially-lit environments. *Indoor Built Environ*. **2015**, 24, 27–36.
15. Amundadottir, M. L., Lockley, S. W., & Andersen, M. Unified framework to evaluate non-visual spectral effectiveness of light for human health. *Lighting Research and Technology* **2017**, *49*(6), 673-696.
16. Lee, J.H.; Moon, J.W.; Kim, S. Analysis of occupants' visual perception to refine indoor lighting environment for office tasks. *Energies* **2014**, 7, 4116–4139.
17. Wang, N.; Boubekri, M. Design recommendations based on cognitive, mood and preference assessments in a sunlit workspace. *Lighting Research and Technology* **2011**, 43, 55–72.
18. Yokoya, M.; Yamamoto, S.; Yamauchi, Y.; Yamamoto, S.; Ouda, O.; Nakaguchi, T.; & Tsumura, N. Subjective evaluation of specular appearance for multiple observations using projector-based appearance reproduction Vol. 6626 LNCS, *3rd International Workshop on Computational Color Imaging, CCIW* **2011**; Milan; Italy;
19. Lee, K.S.; Han, K.J.; Lee, J.W. Feasibility Study on Parametric Optimization of Daylighting in Building Shading Design. *Sustainability* **2016**, *8*, 1220.
20. Hirning, M.B.; Isoardi, G.L.; & Cowling, I. Discomfort glare in open plan green buildings. *Energy and Buildings* **2014**, 70, 427–440.
21. Hirning, M.; Coyne, S.; & Cowling, I. The use of luminance mapping in developing discomfort glare research, *Journal of Light and Visual Environment* **2010**, *34*(2), 101-104.
22. Shen, H.; Tzempelikos, A. Daylight-linked synchronized shading operation using simplified model-based control; *Energy and Buildings* **2017**, (145), 200-212.
23. Švajlenka, J.; Kozlovská, M.; Pošiváková, T.; Čonková, E. Indoor Analysis of Environment in Buildings. *Chemické Listy* **2017**, 111, 398-403.
24. Švajlenka, J.; Kozlovská, M.; Pošiváková, T. Assessment and biomonitoring indoor environment of buildings. *International Journal of Environmental Health Research* **2017**, 27, 427-439.

25. Bawaneh, K., Overcash, M., & Twomey, J. Assessing the utilization of a manufacturing plant floor as part of overhead energy. *Journal of Energy Engineering,* **2015**, *141*(4).
26. Zhivov, A. M.; Case, M.; Liesen, R.; Kimman, J.; & Broers, W. Energy master planning towards net-zero energy communities/campuses. *ASHRAE Transactions* **2014**, *120* (PART 1) 114-129.
27. Katunský, D.; Katunská, J.; & Tóth, S. Possibility of choices industrial hall object reconstruction. Paper presented at the *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM* **2015**, *2*(5) 389-396.
28. Wang, H.W.; Zheng, Y.D.; Tu, F.W. Influences of external windows on energy consumption of industrial buildings in cold areas. *Adv. Mater. Res.* **2011**, 250, 3055–3058.
29. Ferencikova, M.; Darula, S. Availability of daylighting in school operating time; *Light and Engineering* **2017**, 25 (2), 71-78.
30. Moazzeni, M.H.; Ghiabaklou, Z. Investigating the influence of light shelf geometry parameters on daylight performance and visual comfort, a case study of educational space in Tehran, Iran. *Buildings* **2016**, 6, 26.
31. Krüger, E. L., & Fonseca, S. D. Evaluating daylighting potential and energy efficiency in a classroom building, *Journal of Renewable and Sustainable Energy* **2011**, *3*(6).
32. Piderit Moreno, M.B.; Labarca, C.Y. Methodology for assessing daylighting design strategies in classroom with a climate-based method. *Sustainability* **2015**, 7, 880–897.
33. Xue, P.; Mak, C.M.; Huang, Y. Quantification of luminous comfort with dynamic daylight metrics in residential buildings. *Energy Build.* **2016**, 117, 99–108.
34. Nebia, B.; Tabet Aoul, K. Overheating and Daylighting; Assessment Tool in Early Design of London's High-Rise Residential Buildings. *Sustainability* 2017, *9*, 1544.
35. Iringova, A. Impact of external shading on light comfort and energy efficiency in apartment buildings. *Appl. Mech. Mater.* **2017**, 861, 485–492.
36. Mohsenin, M.; Hu, J. Assessing daylight performance in atrium buildings by using Climate Based Daylight Modeling. *Solar Energy* **2015**, 119, 553–560.
37. Berardi, U.; Anaraki, H.K. The benefits of light shelves over the daylight illuminance in office buildings in Toronto. *Indoor Built Environ.* **2016**, 1–19.
38. Gonzalez, J.; Fiorito, F. Daylight design of office buildings: Optimisation of external solar shadings by using combined simulation methods. *Buildings* **2015**, 5, 560–580.
39. Pellegrino, A.; Cammarano, S.; Verso, V.R.; Corrado, V. Impact of daylighting on total energy use in offices of varying architectural features in Italy: Results from a parametric study. Build. Environ. 2017, 113, 151–162.
40. Costanzo, V.; Donn, M. Thermal and visual comfort assessment of natural ventilated office buildings in Europe and North America. *Energy Build.* **2017**, 140, 210–223.
41. Konis, K. Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office building in San Francisco, California. *Build. Environ.* **2013**, 59, 662–677.
42. Mistrick, R.; Casey, C.; Chen, L.; Sarith Subramaniam, S. Computer modeling of daylight-integrated photocontrol of electric lighting systems. *Buildings* **2015**, 5, 449–466.
43. Nasrollahi, N.; Shokri, E. Daylight illuminance in urban environments for visual comfort and energy performance. *Renew. Sustain. Energy Rev.* **2016**, 66, 861–874.
44. Reinhart, C.F.; Wienold, J. The daylighting dashboard—A simulation-based design analysis for daylit spaces. *Build. Environ.* **2011**, 46, 386–396.
45. Amorim, R.; López, J.C.; Molina-Moreno, V.; Peña-García, A. Use of Natural Light vs. Cold LED Lighting in Installations for the Recovery of Victims of Gender Violence: Impact on Energy Consumption and Victims' Recovery. *Sustainability* **2017**, *9*, 562.
46. Shen, E.; Hu, J.; Patel, M. Energy and visual comfort analysis of lighting and daylight control strategies. *Build. Environ.* **2014**, 78, 155–170.
47. Uriarte, U.; Hernández, R.J.; Zamora, J.L.; Isalgue, A. Side-view atmospheres under outdoor midday high luminance. *Buildings* **2016**, 6, 53.
48. Gunay, H.B.; O'Brien, W.; Beausoleil-Morrison, I.; Gilani, S. Development and implementation of an adaptive lighting and blinds control algorithm. *Build. Environ.* **2017**, 113, 185–199.
49. Jia, L.; Afshari, S.; Mishra, S.; Radke, R.J. Simulation for pre-visualizing and tuning lighting controller behavior. *Energy Build.* **2014**, 70, 287–302.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 January 2018 doi:10.20944/preprints201711.0174.v2

50. Doulos, L.; Tsangrassoulis, A.; and Topalis, F. Multi-criteria decision analysis to select the optimum position and proper field of view of a photosensor, *Energy Conversion and Management* **2014**, 86
51. Doulos, L.; Tsangrassoulis A.; and Topalis, F. Quantifying energy savings in daylight responsive systems: The role of dimming electronic ballasts, *Energy and Buildings* **2008**, 40
52. Veitch, J.A.; Whitehead, L.A.; Mossman, M.; & Pilditch, T.D. Chromaticity-matched but spectrally different light source effects on simple and complex color judgments *Color Research and Application* **2014**, *39*(3).
53. Perez, R.; Seals, R.; Michalsky, J. All weather model for sky luminance distribution—Preliminary configuration and validation. *Solar Energy* **1993**, 50, 235–245.
54. Igawa, N.; Koga, Y.; Matsuzawa, T.; Nakamura, H. Models of sky radiance distribution and sky luminance distribution. *Solar Energy* **2004**, 77, 137–157.
55. Katunský, D. Aproximatívny výpočet minimálnych činiteľov dennej osvetlenosti vo veľkorozmerových priemyslových halách. *Building Research Journal* **1992** (40), 299-311.
56. Van Bommel, W.J.M.; van den Beld, G.J. Lighting for work: A review of visual and biological effects. *Lighting Res. Technol.* **2004**, 36, 255–269.
57. Yan, B.; Long, E.; Meng, X.; Zhang, Y.; Hou, D.; & Du, X. Influence of user behavior on unsatisfactory indoor thermal environment. *Energy Convers. Manag.* **2014**, 86, 1–7.
58. Sokol, N.; Martyniuk-Peczek, J. *The review of the selected challenges for an incorporation of daylight assessment methods into urban planning in Poland.* Proc. Eng. 2016, 161, 2191–2197.
59. Chen, K.W.; Norford, L. Evaluating Urban Forms for Comparison Studies in the Massing Design Stage. *Sustainability* **2017**, (9), 987.
60. Labat, M.; Attonaty, K. Numerical estimation and sensitivity analysis of the energy demand for six industrial buildings in France; *Journal of Building Performance Simulation* **2017**, 3, 1-21.
61. Gourlis, G.; Ivacic, I. A study on building performance analysis for energy retrofit of existing industrial facilities. *Applied Energy* **2016**, 184, 1389-1399.
62. Pham, K.; Garcia-Hansen, V.; Isoardi G. Appraisal of the Visual Environment in an Industrial Factory: a Case Study in Subtropical Climates, Solarlits; *Journal of Daylighting* **2016**, Vol. 3, (2), 12-26.
63. Alarcon, B.; Aguado, A.; Manga, R.; Josa, A.; A value function for assessing sustainability application to industrial buildings. *Sustainability* **2011**, 3, 35–50.
64. Katunsky, D.; Dolnikova, E.; Doroudiani, S. Integrated Lighting Efficiency Analysis in Large Industrial Buildings to Enhance Indoor Environmental Quality. *Buildings* **2017**, 7, 47.
65. Lombera, J.T.; Rojo, J.C. Industrial building design stage based on a system approach to their environmental sustainability. *Construct. Build. Mater*. **2010**, 24, 438–447.
66. Lombera, J-T.S-J; Aprea, I.G. A system approach to the environmental analysis of industrial buildings. *Building and Environment* **2010**, 45, 673–683.
67. *Integral Lighting*, ČSN 360020; CZ Office of Standards, Metrology and Testing Prague, Czech Republic, **2015**.
68. STN 730580; *Daylighting in buildings, Part–1 Basic requirements*, 1986 *Part–2; Daylighting of residential buildings*, 2000, Slovak Republic Office of Standards, Metrology and Testing: Bratislava, Slovakia; **2000**
69. EN 12464-1:2012. *Light and Lighting; Lighting of Work Places-Part 1: Indoor Work Places*; Slovak Republic Office of Standards, Metrology and Testing: Bratislava, Slovakia, **2012**
70. CEN/TC 169 07/**2017** *Daylight in buildings* (TC 169 WI 00169068), **2017**
71. International Energy Agency (IEA) *Solar and Heating Cooling Program*, Task 31—*Daylighting Buildings in the 21st Century.* Available online: http://task31.iea-shc.org/ (accessed on 2 May **2017**).