Daytime Lighting Assessment in Textile Factories Using Connected Windows in Slovakia: A Case Study

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Abstract: This 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 daylight (as part of integral light) in the production halls marked F and G. This study follows the article in the Buildings journal, where Hall E was evaluated (unilateral daylight). These two additional halls have large areas that are 54 × 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 the 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 the case studies can be applied in similar production halls illuminated by a 'double-sided' (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-storied industrial buildings. The proposed approximate calculation method for the daylight factor can be used to predict the 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]. Furthermore, Tsangrassoulis, A. et al. [2] deals with the prototype of the hybrid daylight system. Some other aspects play important roles for daylight, such as dimming in relation to daylight (Doulos, L. et al. [3]). Doulos, L., et al. [4] also describes the role of the spectral response of photosensors in daylight response systems. One of the well-known authors dealing with daylighting and its impact on building users is Belia, L. [5,6].

The influence of daylight during the daytime on human health was studied by 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] and Smolders, K. C. et al. [10]) as well as the visual perception of interiors (Yao, J. et al. [11] and Fabi, V. et al. [12]). Gou studied the visual comfort and light simulated effects in relation to workers' productivity and well-being [13,14]. Daily lighting and its visual and non-visual perceptions of the indoor environment impacts the performance of people in the building. Research on the nonvisual daytime light effects on humans in buildings for non-visual health potentials, visual interest and observed behaviour is found in the work by Amundadottir, M. L. et al. [15] and visual perception (Lee, J. H. et al. [16]). Direct sunlight and its effects are investigated by Wang, N. et al. [17],

Yokoya, M. et al. [18], and Lee, K. S. et al. [19]. A barrier to dazzle and unpleasant dazzling is described by Hirning, M. B. et al. [20,21]. Shen monitors a 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 the overall assessment of the internal environment (Švajlenka, J. et al. [23,24]).

Building design, depending on the daylight, is described in the book Handbook for Architects and Engineers (Baker, M. & Steemers, K. [25]). Industrial buildings have certain features when designing lighting. This problem is addressed in the book Handbook of Industrial Lighting (Lyons, L.S. [26]). A whole range of problems related to the design of lighting openings in industrial buildings has been described by Dolniková, E. and Katunský, D. [27]. The problem associated with designing and evaluating windows in terms of daylight lighting is given by Kalousek, M. & Mohelníková, J. [28].

In terms of indoor lighting, various types of buildings that require demanding visual activities are examined in the literature. Educational buildings and schools are dealt with by Ferencikova, M. and 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]; and 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 modelling of the photocontrols of electric lighting systems that are integrated daily. The simulation and modelling of daylight are 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 is described by Shen, E. et al. [46], and the lateral and visible atmosphere is described by Uriarte, U. et al. [47]. Adaptive light is tracked by Gunay, H. B. et al. [48] and a simulation to visualize and debug the behaviour of the lighting regulator is done by Jia, L. et al. [49]. An analysis of several criteria for selecting the optimal position and the correct field of view of the photosensor that is required in a building as well as the quantification of energy savings in daylight response systems in the dimming function of electronic ballasts is studied by Doulos, L. et al. [50,51]. Chromaticity-matched but spectrally different light effects sources on simple and complex colour judgments are studied 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, daylight is very important in industrial halls for visual convenience. Especially for human vision 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 cause unpleasant scattering in the interior. Daylight may also weaken performance by creating shadows in the workplace. The effectiveness of electrical artificial lighting during the daylight depends on the quality of the light sources and their similarity to the radiation of daylight. Therefore, the negative aspects are also positive in daylight. Integral lighting is dealt with and certain conditions are proposed by Katunský D. [55]. Lighting conditions at the workplaces were examined using both practical and mathematical methods by Van Bommel, W. J. M. and van den Beld, G. J. [56]. The influence of user behaviour on unsatisfactory indoor thermal environments is described by Yan, B. et al. [57].

The incorporation of methods of daylight assessment into urbanization was studied by Sokol, N. and Martyniuk-Peczek, J. [58] and Chen, K. W. and Norford, L. [59]. These considerations have motivated us to do this research into daylight systems in order to improve the quality and comfort of interiors for workers while reducing energy consumption. The study of six industrial halls in France was published by Labat, M. and Attonaty, K. [60]. A similar problem in the industry is also addressed by Gourlis, G. and Ivacic, I. [61] and 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

96   industrial factory (a case study in Slovakia) was examined by Katunský, D. et al. [64]. New models for
97   sustainability assessment criteria in industrial buildings have been developed (Lombera, J. T. & Rojo,
98   J. C. [65]). The modified criteria for the assessment of the sustainability of industrial buildings have
99   resulted in the development of new models by Lombera, J. T. and Aprea, I. G. [66]. In this text, we
100 want to outline the continuation of research aimed at ensuring minimal daylight conditions
101 throughout the day in large-scale floor plans.

2. The Aim of the Research

103   In the design, construction, and operation of manufacturing buildings, it is necessary to consider
104 the requirements for the sustainability of the buildings. Specifically, we are interested in the
105 microclimate of the interior of industrial buildings focusing on the indoor light microclimate, the
106 thermal humidity, and other factors with an emphasis on energy saving in operation. Last but not
107 least, is building sustainability. The design requirements for the construction and operation of
108 production facilities should consider the requirements in order to achieve sustainability. In particular,
109 we are interested in the indoor climate in the interior of industrial buildings, focusing on indoor light,
110 acoustic, thermal-humidity and other types of microclimates with an emphasis on energy saving
111 aimed at building sustainability conditions.

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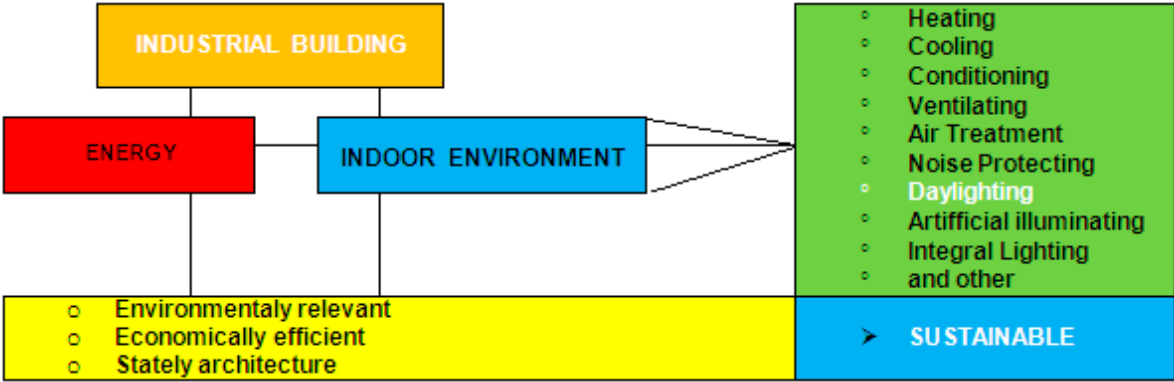


Figure 1. The design of industrial buildings and the role of daylight for the indoor environment and
114 the sustainability requirements.

115   An industrial building must be environmentally relevant, economically efficient, with stately
116 architecture so that it leads to sustainability even within the industry (see Figure 1). In this paper, we
117 are primarily concerned with the daytime lighting through window constructions in industrial and
118 indoor environments and the lighting conditions in industrial buildings.

2.1. Methodology

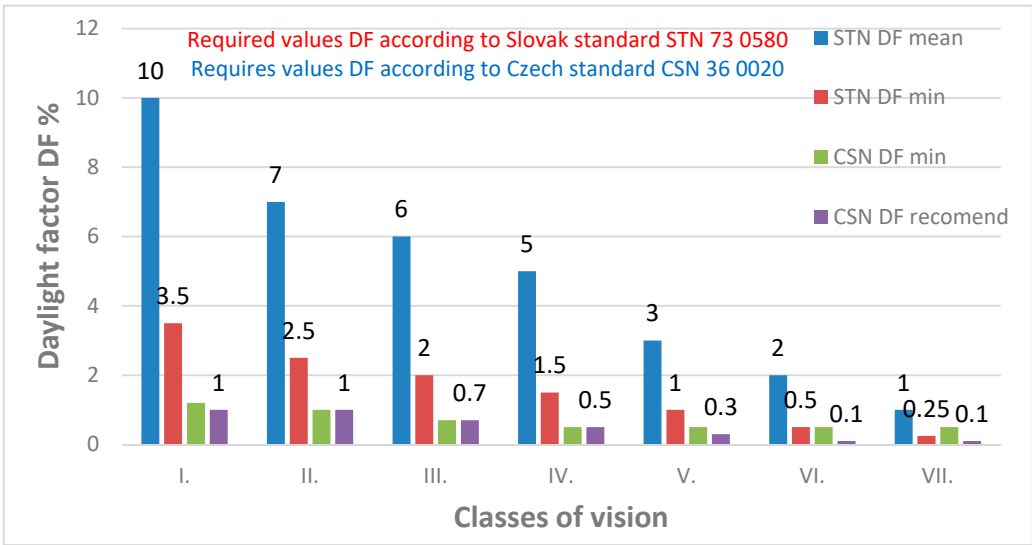
120   In this article, we take into account the daytime lighting in an industrial factory (a textile factory)
121 outside the city where one hall is above the other (one interior is above the other and there is no
122 shading). The production halls are referred to as A, B, C, D, and so on. We are only interested in one
123 part of the indoor environment—daylighting. It is not possible to meet the daylight requirement for
124 visibility at remote locations with unilateral daytime lighting (on only one side), as shown in
125 Reference [64], where the hall is marked as 'E'". The case study in this document points out how there
126 is illumination from two parties (that is, bilaterally) in the 'F' and 'G' halls.
127   If we cannot meet the requirements for daylight there must be a combination of daylight and
128 artificial lighting; for example, integral or integrated lighting. The task is to determine the
129 methodology for determining the minimum required Daylight Factor (DF) for integral lighting, as
130 prescribed by the Czech Technical Standards (CSN). The research was carried out in textile halls in a

131   town located in the eastern part of Slovakia. In this work, we present two knitting factories of the
132   textile industry which have different window locations. The predominant role of this research is to
133   analyze the impact of window placement on the daylight industrial hall lighting with regard to
134   integrated dynamic simulations and real in situ measurement methods. The on-going view offers an
135   analysis of the daylight conditions that also use measurements in situ and calculation by simulation,
136   leading to the design of windows and the optimization of sustainability monitoring.
137   This work is a continuation of the comprehensive research of the quality of the internal working
138   environments (internal microenvironments) of industrial buildings.

139   *2.2. Daylighting According to Czech (CSN) and Slovak (STN) Standards*

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

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

147   Prescription of the DF according to the Slovak standards is shown in Figure 2. The rule for the
148   minimum and average daily DF factor for all seven categories of technical light recognition (see Table
149   1) according to the Slovak and Czech national standards can be seen in Figure 2.

151   **Figure 2.** The comparison of the Daylight Factor (DF) prescription according to Czech standard
152   CSN 36 00 20 (Integral lighting) [67] and Slovak standard STN 730580 (Daylighting) [68]**.**

153   The classification of the internal daylighting indoor-environment according to Slovak and Czech
154   technical standards is based on the work, its complexity and the basic requirements that are placed on
155   the complexity of the visual activity.
156   Artificial lighting is determined with EN 12464-1 2011 'Light and lighting—Lighting of
157   workplaces, Part 1 Indoor work places' for 'night time conditions' only Reference [69]. Namely, the
158   corresponding light levels from the artificial lighting system are calculated without the influence of
159   daylight. Thus, only the combination of daylight and artificial light should be with the use of
160   photosensors. However, this is not the subject of our research.

161   In Czech standards of 'Integral lighting in buildings' [67], interiors are classified into seven
162   groups according to the intensity of the visual activities performed inside a building. This is similar to
163   the Slovak standards [68]. The values of the DF are grouped into seven categories representing human
164   eye recognition for visual detail tasks. The main starting point for determining the requirements for
165   integral lighting is the classification of the visual activities performed in a building according to
166   References [67,68] (Figure 2).

167   **Table 1.** The classification of human eye recognition of visual detail tasks according to the Slovak national
168   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 artwork
III.	**Precise operation**	Precision manufacturing and inspection, regular drawing, technical drawing, consuming laboratory, labour-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

169   The same classification applies to the daily STN standards and the CSN integral lighting. The
170   same applies to the relative observation distance. The difference is in the prescribed minimum DF
171   factors (see Figure 2) as well as differences in the permitted luminance.
172   Problems related to industrial buildings have not been thoroughly reviewed until such details as
173   another type of buildings. The criteria for residential and civil non-manufacture buildings do not
174   apply to industrial buildings. Therefore, it is necessary to make certain changes in the methods and
175   approaches to assessing the design of buildings in the industrial sectors.

176   *2.3. Daylighting According to European Standards*

177   In the draft of the European standards, the rules are slightly different from national standards.
178   Other factors are taken into account here. This standard evaluates permanently inhabited areas,
179   classifies buildings' premises according to function and work activities, and defines areas with
180   daylighting requirements. The daylight assessment features are applied mainly to industrial areas,
181   offices, civic areas, schools, health-related buildings, business and apartment buildings, and prisons
182   and care homes. The daylight availability is determined by the median of horizontal diffuse
183   illumination at location E_{med}. Daylight is intended to provide levels of natural light higher than the
184   critical visual daylight lighting level of 300 lx. The daily lighting requirements should be adequate,
185   with an acceptable minimum of 100 lux. The target factor D_T is the daily lighting factor to be achieved
186   in a certain portion of an area in order to meet the daylighting criterion. On the working plane, the
187   illumination level is 300 lx. The daylighting factor D_{TM} is the minimum target daylight factor. This is
188   the minimum DF value in a specific location that corresponds to the illuminance level of 100 lx. Basic
189   daylighting requirements according to the draft of the European standards [70] can be seen in Tables 2,
190   3, and 4:

191 **Table 2.** The maximum permissible brightness (luminance) of the subject observed and the brightness of the
192 illuminating opening positioned 60° from the normal viewing direction according to European Union (EU)
193 standards.

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

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

196 **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 the 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 Reference [70] states that the target daylight factor (D_T) and the minimum target daylight factor (D_{TM}) corresponds to the target illuminance level and the minimum target illuminance, respectively, for the European Committee for Standardization (CEN) capital cities.

197 **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 the 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 1.25 m (width x height).

198 The draft of the European Union (EU) standards shows the values of the DF for daylight
199 openings exceeding an illuminance level of 100, 300, 500 or 750 lx for a fraction of the daylight hours
200 F_{time} (%) = 50% for 33 capitals of Committee for Standardization (CEN) national members. The values
201 of the DF only for horizontal daylight openings with diffusing material exceeds an illuminance level
202 of 100, 300, 500 or 750 lx for a fraction of daylight hours F_{time} (%) = 50% for 33 capital cities of CEN
203 national members [70].

3. A Case Study: Textile Factory

The subject in this case study is a textile factory located in the eastern part of the Slovak Republic in which two 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 factory called A, B, C, D, and so on. In Reference [64], we considered hall E and in this paper, we evaluate hall F and hall G, which are illuminated by daylight from two sides.

(a) Situation of case study

(b) Bilateral windows—halls F, G

(c) Luminance, Internal view "F"

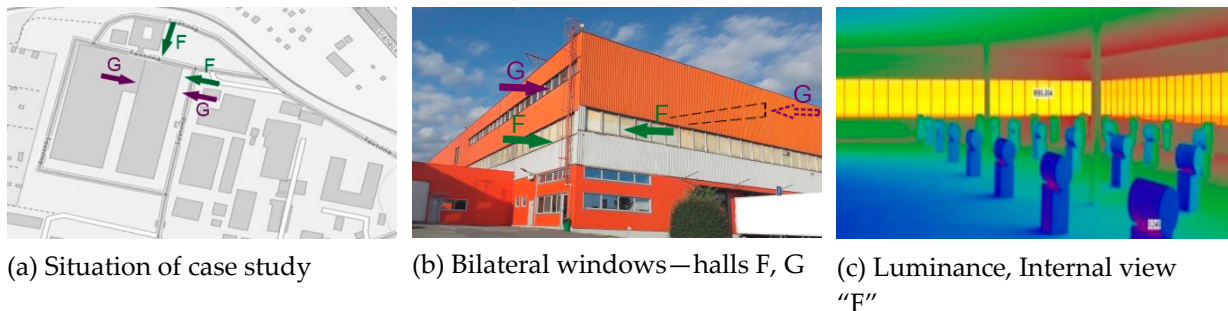



Figure 3. The situation of a textile factory placement, lighting simulation results near windows in the double-side window day illumination.

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 showcase 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 the neighbouring 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 of the DF,

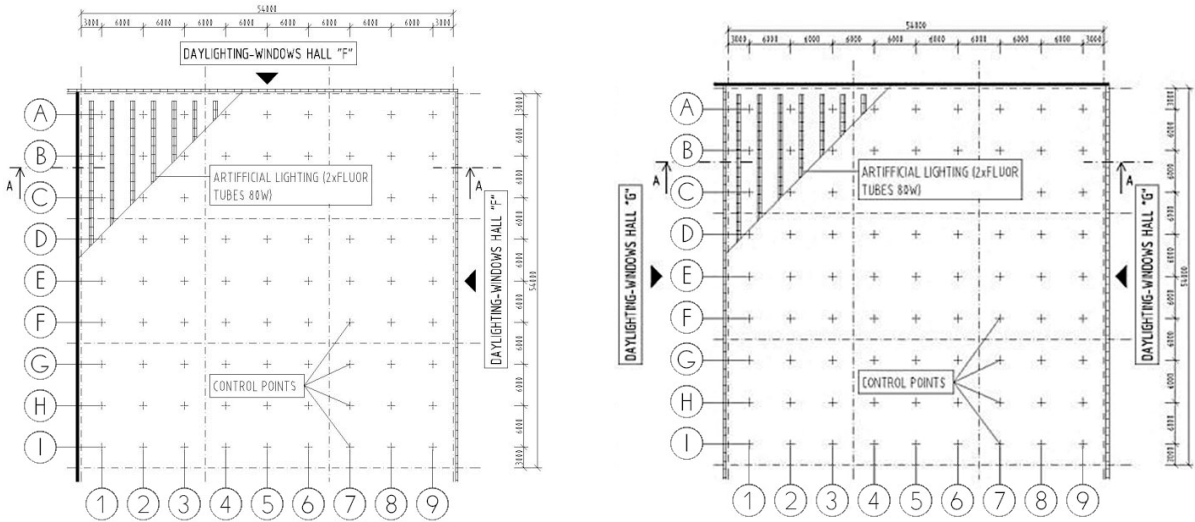
3) calculation and simulation of the daylight situations using the simulation program,

4) confrontation of measured and calculated DF values,

5) and the derived simplified formula for the window design depending on the floor area to determine the minimum DF (for integral lighting as a basis).

3.1. Daylight Measurements

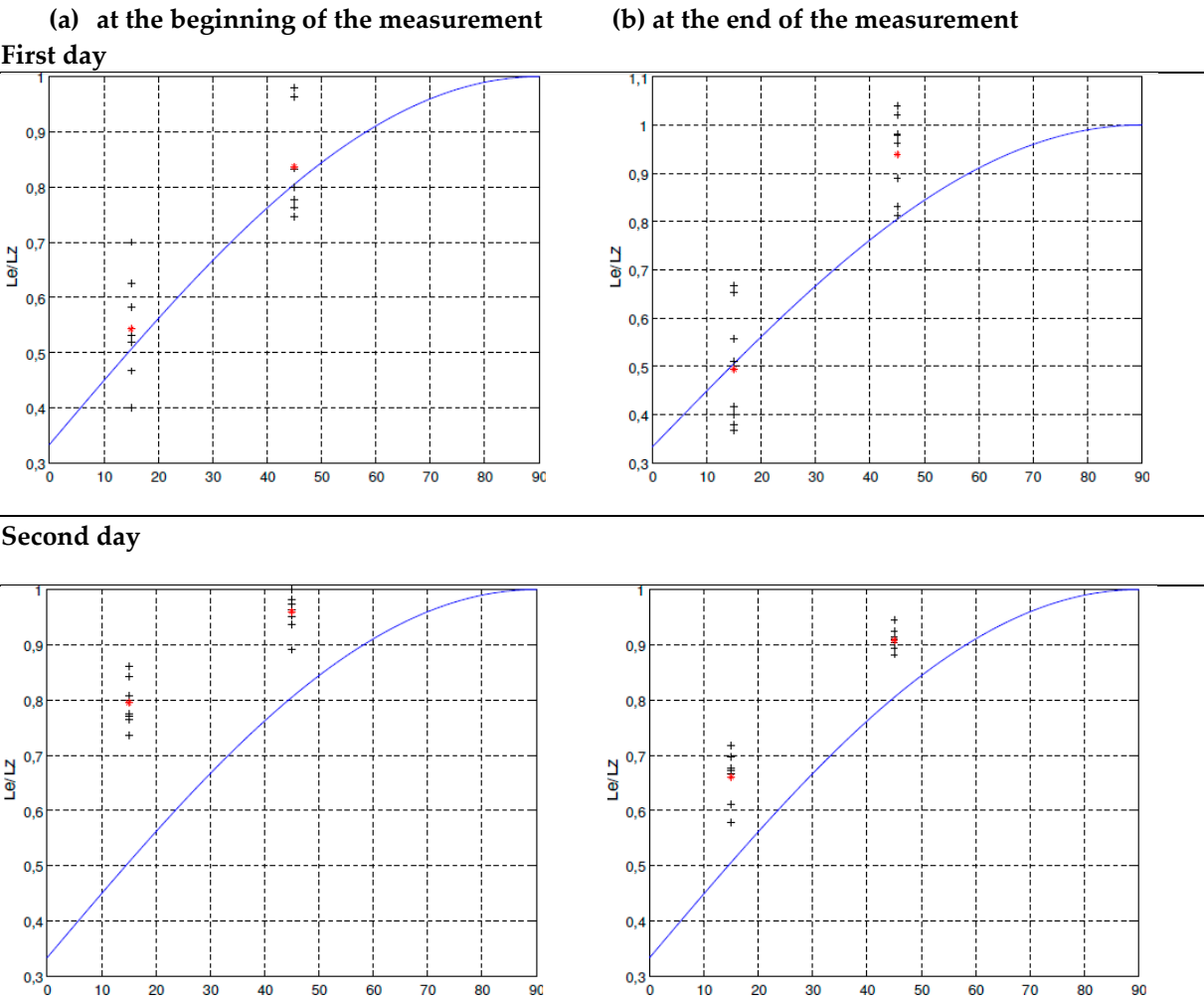
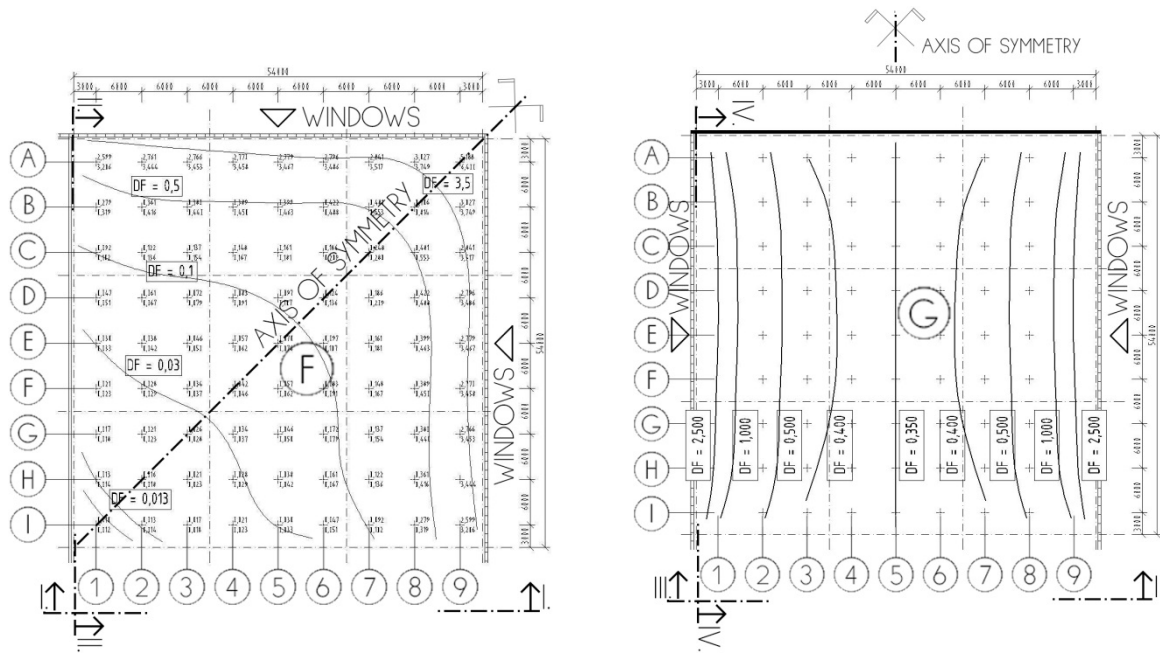
Daylight measurements were performed according to Slovak standard 'Measurement of daylighting'. The measuring instruments were borrowed from the STU Faculty of Civil Engineering in Bratislava. The instruments were two 'Hagner EC 1 type' lux meters with the following production numbers: 5532 and 5531, a 'Hagner Universal Photometer type S2, S22065' with an accuracy of 5%, and the 'Hagner Reference calibration sample' with a 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%, and the uniformity of the illumination is more than 0.2–0.3 for a given visual task. According to standard measurements of daylighting, the change in the luminance of the sky at a given height to sky luminance in zenite at 15° is 0.3–0.6 and 0.7–0.85 is acceptable at 45° (see Figure 5). Daylight measurements were performed on two different days when the artificial lighting system was switched off. Control points during the measurement were from the floor at 850 mm, because the need for visual power is at a given height. Measurements were performed at 81 control points simultaneously with two lux meters. It was measured in nine rows (direction E–W) labelled A–I at distances of 3, 9, 15, 21, 27, 33, 39, 45, and 51 m from the edge of the peripheral wall. In the longitudinal direction of the hall, it was also measured in

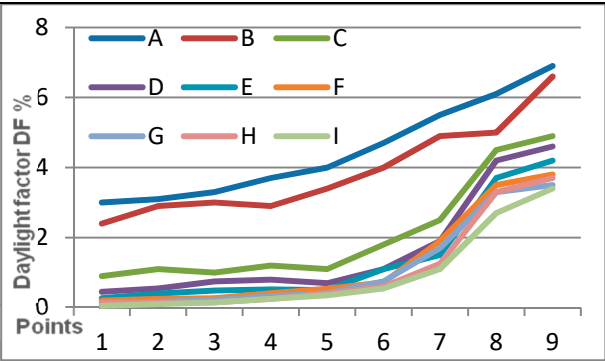
242   nine rows marked 1–9 at distances of 3, 9, 15, 21, 27, 33, 39, 45, and 51 m from the peripheral wall edge
243   (Figures 4 and 6).

245   **Figure 4.** The floorplan of halls F and G.

246   If the device is unable to take a measurement at the specified points, the value is measured at
247   approximately 30 cm–50 cm outside the point. One light measuring device measured illumination at a
248   designated location inside the hall. The second light measurement was external, on a horizontal
249   surface (on the roof). Daylight measurements were performed on the first day twice and the other
250   days three times (see Figure 5). At the level of the roof structure, the measurement of the outdoor
251   horizontal illumination and the external illuminance (see Equation (1)) was measured on a plane that
252   was not shaded.
253   On the selected days, the value of the outside light in a cloudy sky ranged from 4000 lx–8000 lx
254   on the first day and 5000 lx–8000 lx on the second day, when the light was measured in the direction
255   of the cardinal. The measurements of the luminance distribution in the clouds at the measuring site
256   were performed on both days at the beginning and at the end of the measurement. The comparison of
257   the measured values with the normalized luminance distribution of an evenly cloudy sky on the dark
258   terrain is shown in Figure 5. The final DF values measured at the control points are shown in Figure 7.
259   From the graphs in Figure 5, it can be seen that the values of the sky luminance at the specified
260   altitude before and after the measurement were done are almost within the allowed range. The results
261   of the measurement values can be seen in Table 5.

262   **Table 5.** The measured sky conditions rating gradations of sky luminance.

First day					
(a) at the beginning of measurements			**(b) at the end of measurements**		
Z	Le/Lz	Average value	Z	Le/Lz	Average value
15°	0.4–0.7	0.55	15°	0.35–0.68	0.50
45°	0.75–0.85	0.85	45°	0.80–1.05	0.92
Second day					
(a) at the beginning of measurements			**(b) at the end of measurements**		
Z	Le/Lz	Average value	Z	Le/Lz	Average value
15°	0.774–0.86	0.80	15°	0.61–0.72	0.68
45°	0.89–1.0	0.95	45°	0.88–0.92	0.90

263   The measured sky conditions rating gradations of brightness (sky luminance) in the two
264   considered days in December and January can be seen in Figure 5. In Figure 5 x refers to the elevation
265   angle and y to the Le/Lz ratio.

266   **Figure 5.** The measured sky conditions rating gradations of sky luminance, x refers to the elevation
267   angle, y refers to the Le/Lz ratio, Le refers to the external sky luminance, and Lz refers to the sky
268   luminance at an angle of Z 15°and 45°.

269
270 **Figure 6.** Schematic pictures of the predicted lines with the same DF in halls F and G at 81 control
271 points (from A1–I9), indicating sections I-I, II-II, III-III and IV-IV for displaying the measured values.

272 Daylight measurements were made in December and January when the sky was cloudy.
273 The DF values shown in Figure 7 are calculated from the measurement results as the average value of
274 the five measurements. From these data, the DF evaluation parameters that are shown in Figure 6
275 were calculated. The spatial distribution of DF, the curves of the same brightness curves, and the DF
276 curve decreases with respect to the depth of the space being considered. This is similar in Figures 8, 9,
277 and 10.
278 The light reflection factor was determined according to the standards. Luminance was located
279 according to the wall, ceiling, floor, and interior. From the measured luminance values of the
280 individual surfaces and the known reflection factor of the calibration sample, the resulting reflection
281 factor of the measured surfaces was calculated. The values of the calculated reflection factors were
282 used as inputs for assigning the properties of the material surfaces in the hall.

Hall "F" section I-I   Hall "F" section I-I

Hall "G" section III-III   Hall "G" section IV-IV

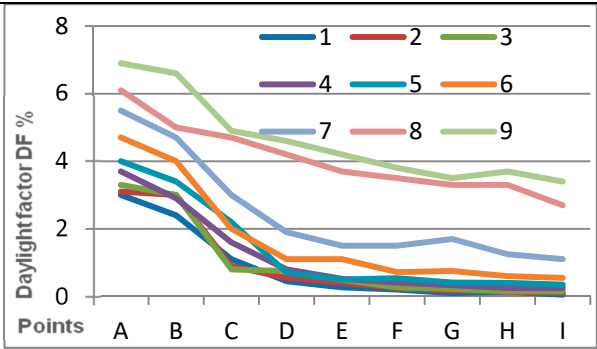
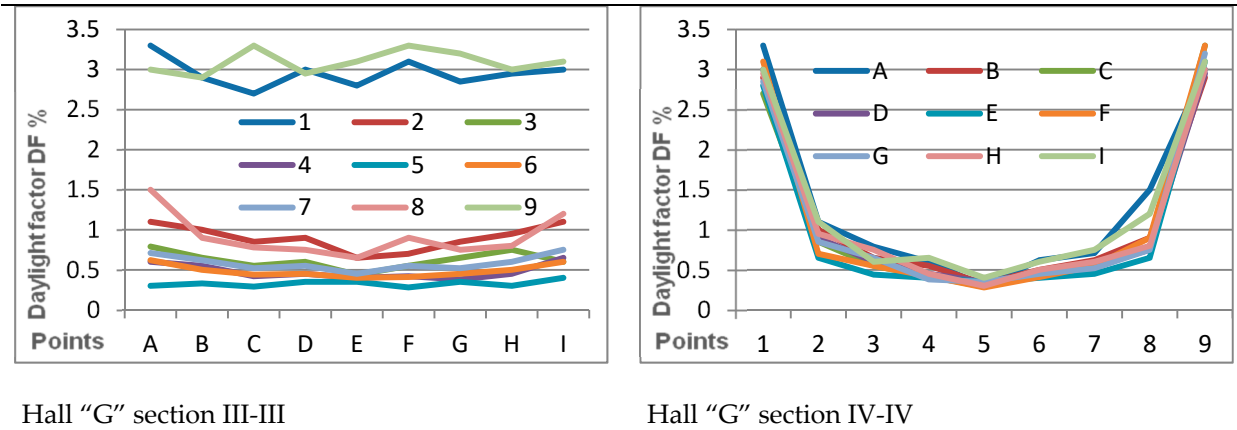



Figure 7. The measured *DF* values at the control points in halls F and G in sections I-I, II-II, III-III and IV-IV.

3.2. Daylight Calculations

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

The external illuminance is considered to be 5000 lx; (in the draft EU standards it is considered different for every capital city of the 33 EU members. For Bratislava (Slovakia) it is 16,300 lx). The height of the interior space of hall is 5100 mm. The parapet is at a height of 1200 mm. The dimensions of the windows—the height of the window strip is 2400 mm and the wall thickness varied between 100 mm–300 mm.

The light loss coefficients, normal light transmittance $\tau_{glazing} = \tau_1 = 0.92$. The influence of the frame on light transmittance of windows $\tau_2 = 0.74$. The influence of glass cleanliness $\tau_3 = 0.80$ and the influence of interior and shading elements $\tau_4 = 1.0$.

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

The 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. The halls reduce the DF due to the depth of the track.

The results of the 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 'G' luminance (cd/m²) in a sunny sky |

 |
| --- | --- |

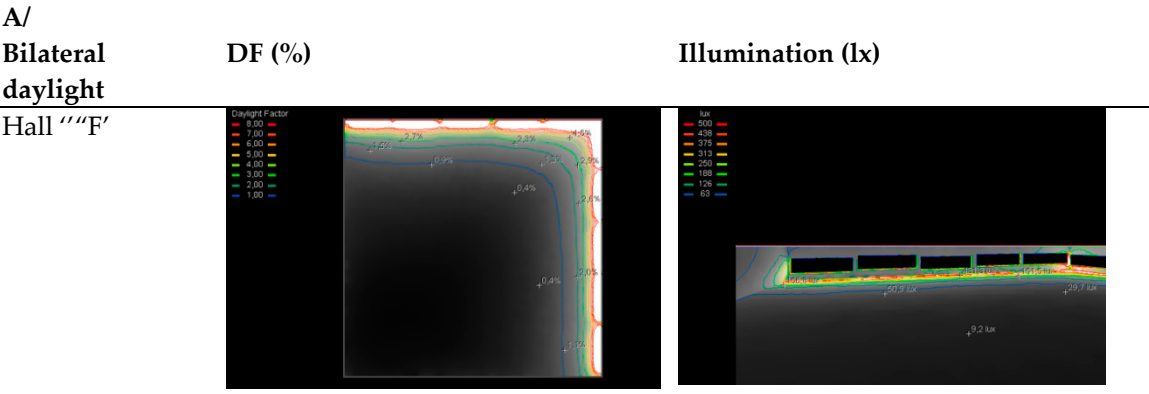
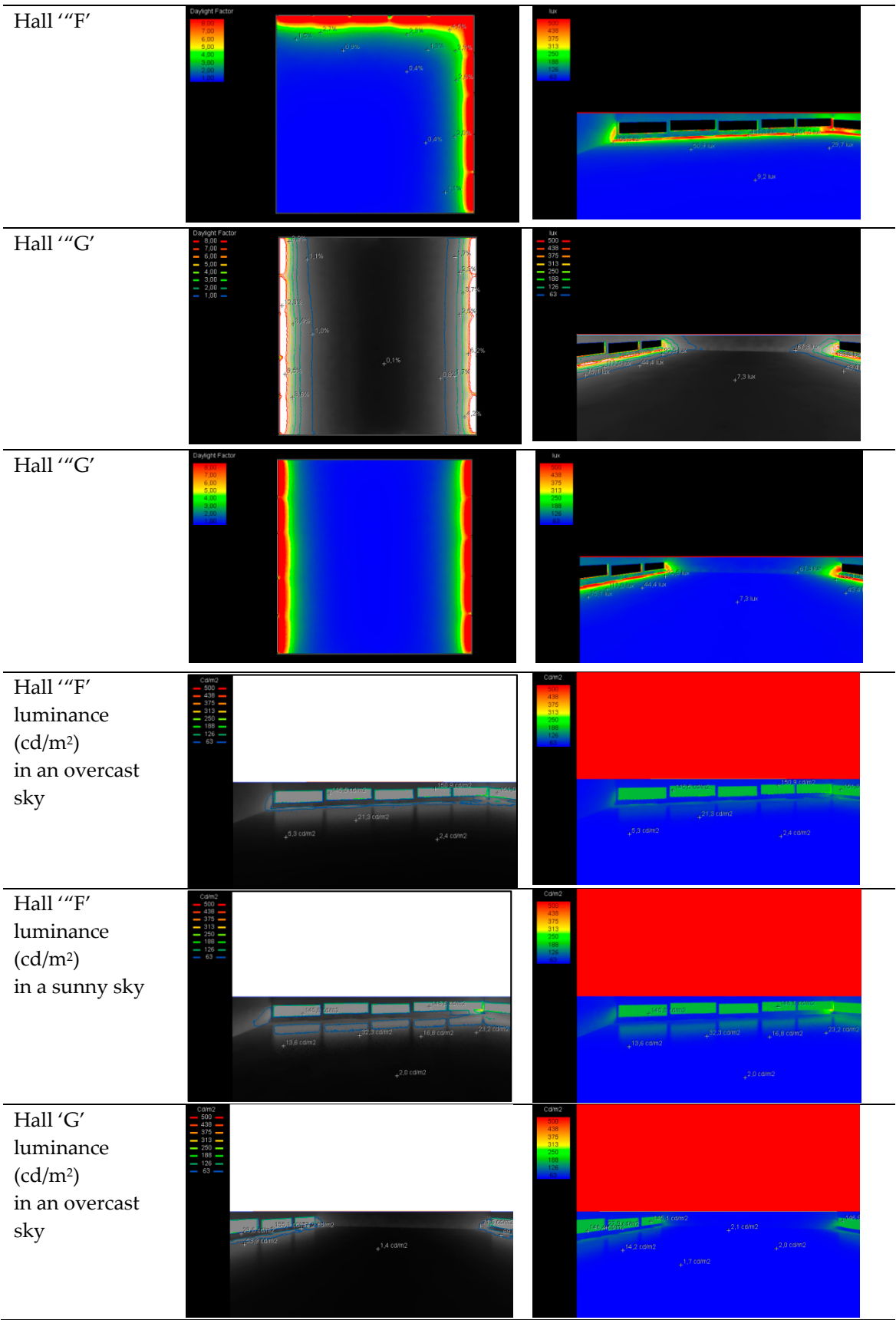
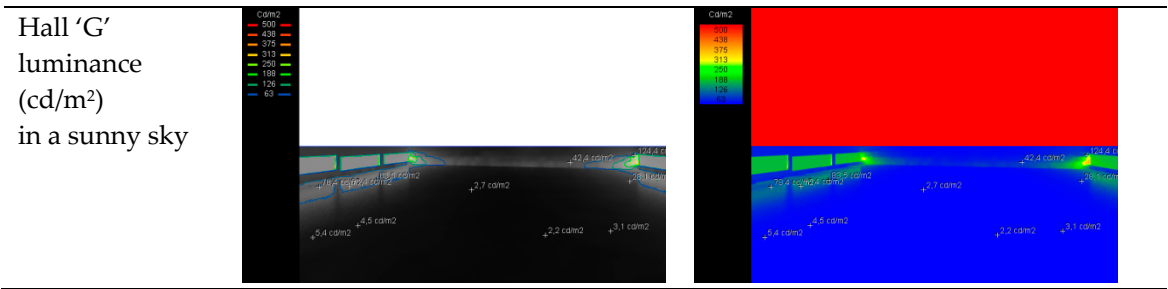
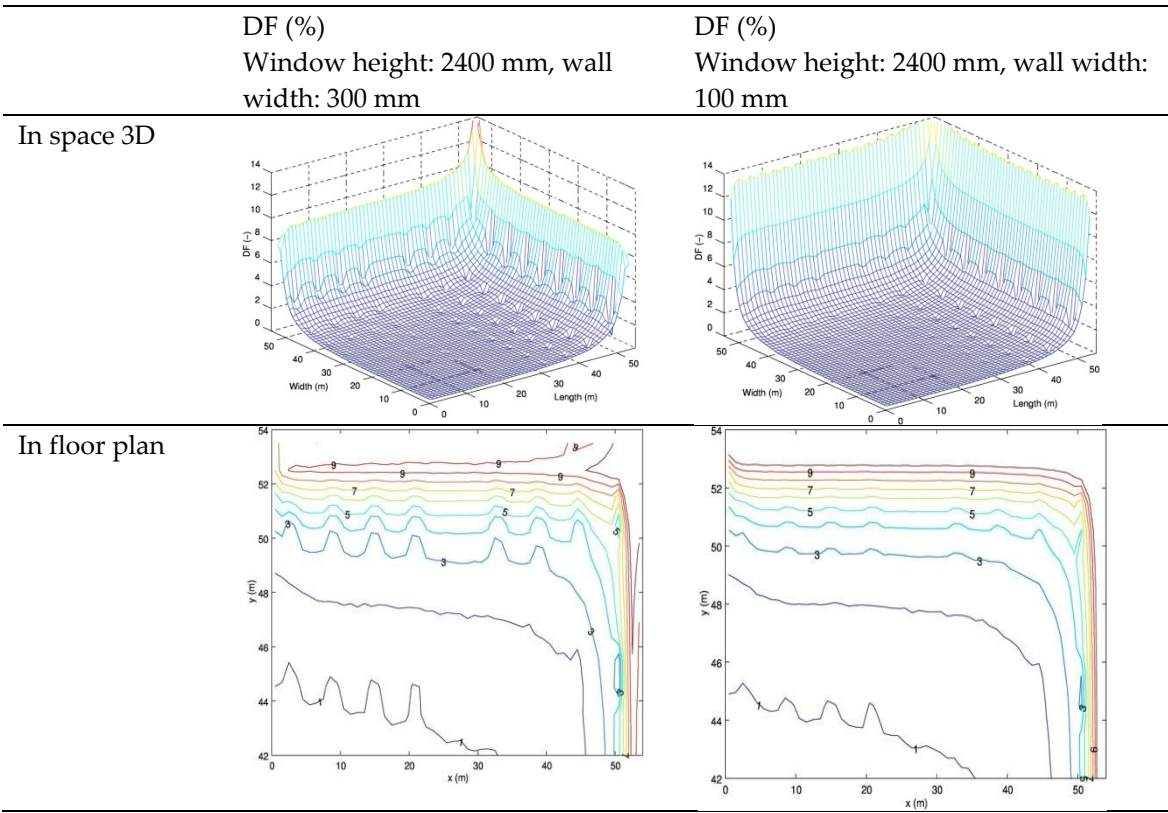
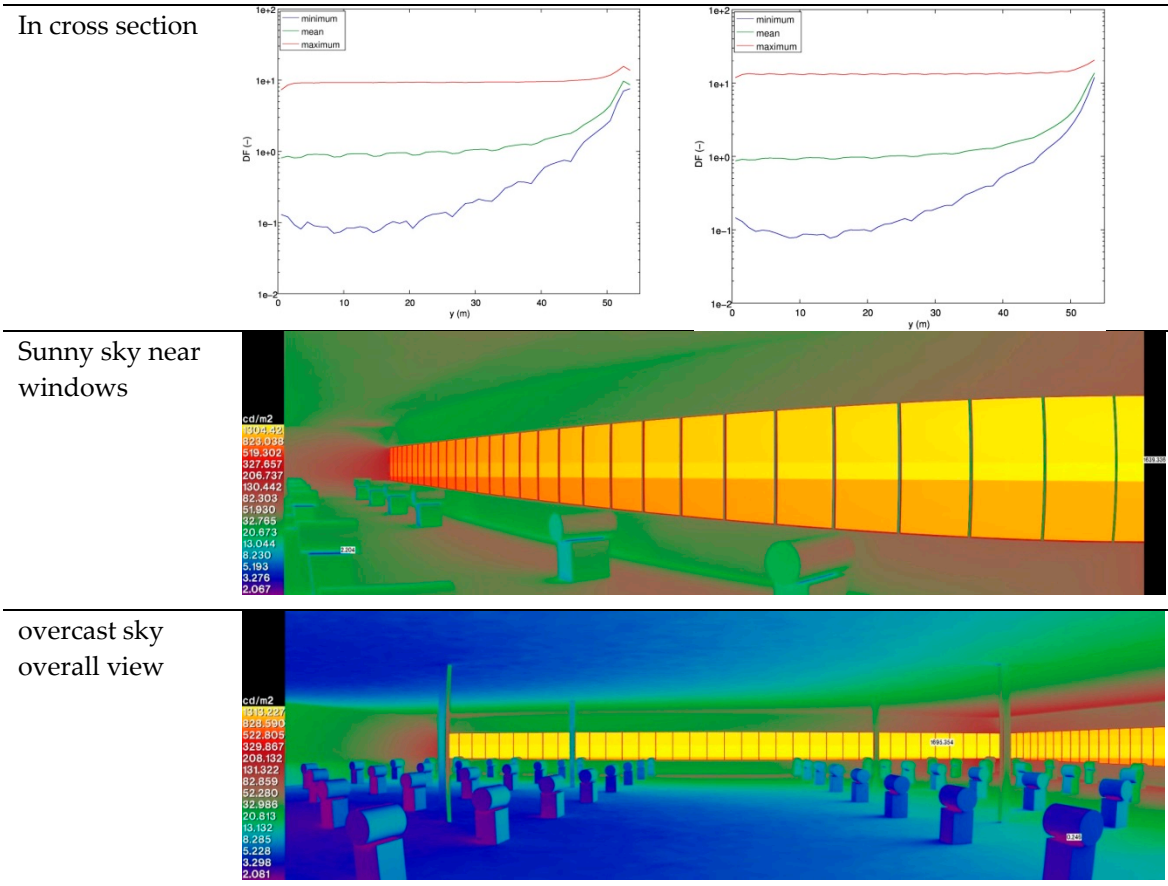



Figure 8. Results of the daylight factor *DF* (%), illumination *I (lx)*, and luminance (cd/m²) in halls F and G calculated in an unfurnished interior.

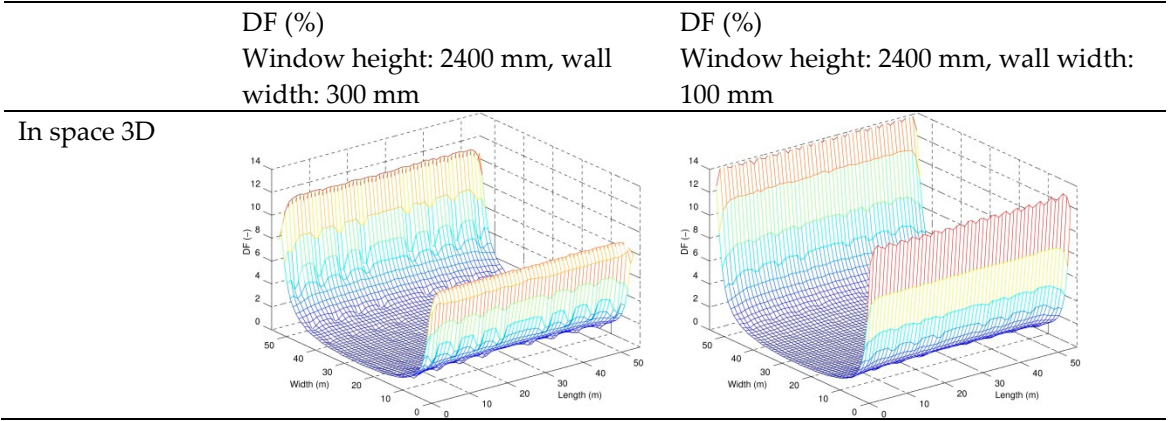
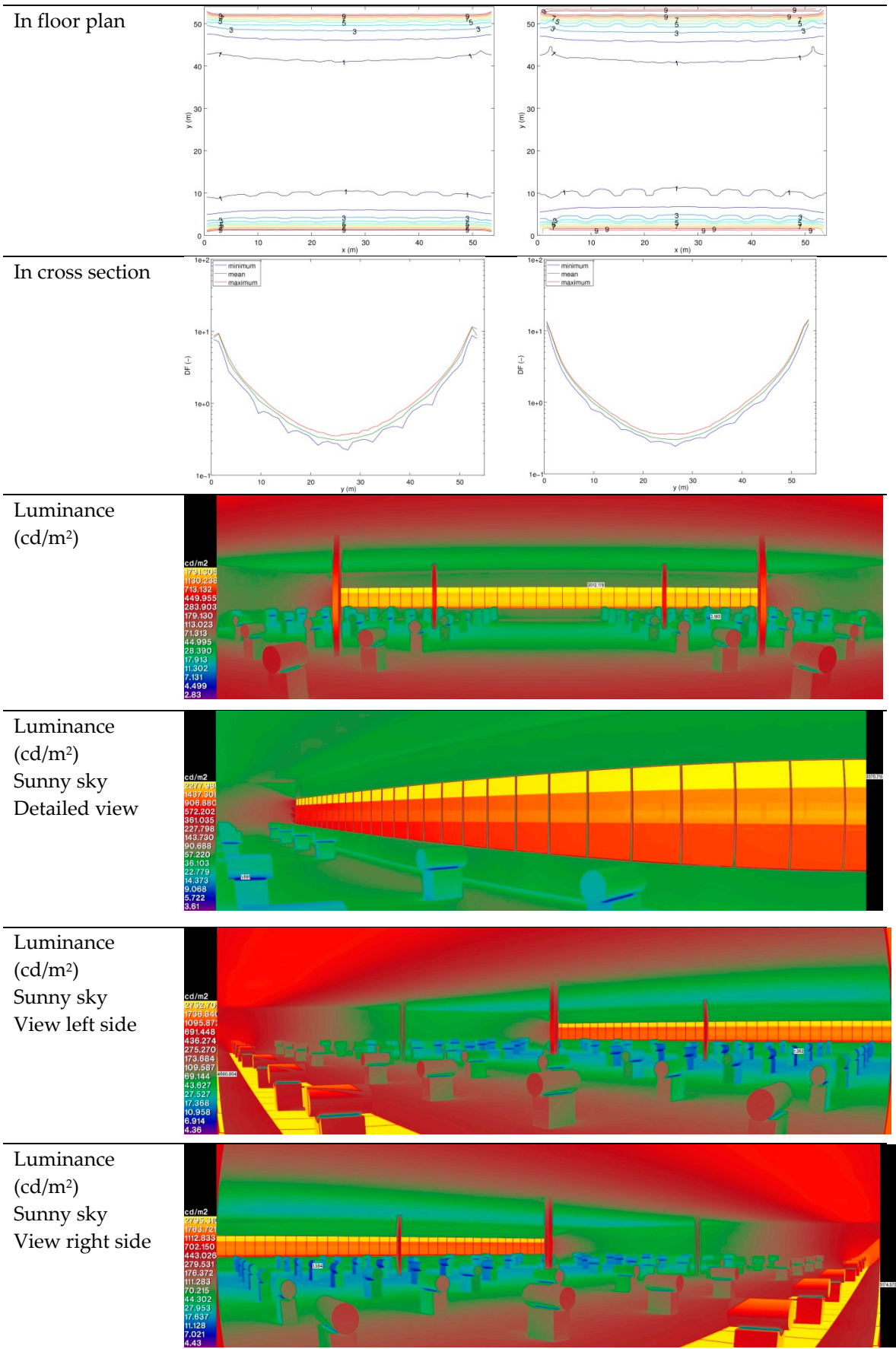
In hall E, the daytime lighting was provided on one side only (see Reference [64]). The results are similar to those in halls F and G, except that the symmetry is different. In hall F, the symmetry axis is diagonal across points A9–I1 (Figure 6). In hall G, it is in the centre through points A5, B5, C5, and so on to I5. In hall F, there were no duplications of results at any of the points, despite the fact that the lighting was from two sides. In hall G, the daylight factor can be determined by the superposition of values. It is the sum of the highest value near the windows and the lowest value at the extreme point. At other points, the results are mirrored (Figure 6). When it comes to simulation programs, this 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 furnished interior can be seen in Figure 9.

	DF (%) Window height: 2400 mm, wall width: 300 mm	DF (%) Window height: 2400 mm, wall width: 100 mm
In space 3D

 | |
| In floor plan | | |

In cross section		
Sunny sky near windows		
overcast sky overall view		

319   **Figure 9.** The results of the daylight factor *DF* (%) and illumination *I (lx)* in hall F and results of
320   luminance (cd/m²) in hall F with the hall equipment calculated by the radiance simulation program.

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

	DF (%) Window height: 2400 mm, wall width: 300 mm	DF (%) Window height: 2400 mm, wall width: 100 mm
In space 3D		

324   **Figure 10.** The results of the daylight factor *DF* (%) and illumination *I (lx)* in hall G and the results of
325   the luminance (cd/m²) in hall G with the hall equipment calculated by the radiance simulation
326   program.

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

332   *3.3. Evaluation of the Case Study*

333   The values of the selection characteristics of a set are calculated at each measurement point. In the
334   creation of the hall model, the marginal conditions were created based on measurements in the hall.
335   Individual measured material constants (factors of reflection of surfaces, pollution factors, and glazing
336   permeability) were considered. In this study, the results of measurement and calculation data for the
337   control points are also presented. By comparing the calculated and measured data, we can conclude
338   that the course is similar. As far as the level of daylight is concerned, there are differences. The DF has
339   three components 1-sky DF_{sky}, 2-reflective inner components DF_i, and 3-reflective outer components
340   DF_e that can be calculated as $DF_{reflected}$ (see Reference [64]). This is calculated in most cases together and
341   has the value of $DF_{reflected}$. Relationships 2–4 can be used for Dw points based on the above analysis.
342   The diameter $DF_{reflected}$ can be used as the DF factor in the centre of the space considered, where the
343   windows are the same (hall F). The DF measured value (in hall F) is almost twice as high in close
344   proximity to the windows as it is in hall G, where the windows are opposite (Figure 6). The lowest DF
345   level is in the outermost positions of the windows (point I1 in hall F and in the symmetry axis of hall
346   G—points A5–I5). The noticeable impact of daylight can be seen at points about 9 m away from the
347   windows. Then the level of daylight shifts sharply. The resulting measured value approximates to
348   DF_{sky}. The DF values may be lower due to device shading. This is shown in Figure 8, where the results
349   are obtained using a calculation simulation program.
350   Changing the level of the reflection component $DF_{reflected}$ at the distance from the daylight
351   opening Dw is expressed by Equation (2) [64]. The reflected component DF at the distance Dw from
352   windows changes from $D_{\rho, min}$ to $D_{\rho, max}$ with an average $D_{\rho, mean}$ value. This value is the average in the
353   centre of the space under consideration. The *DF* can be expressed by Equation (3).

354
$$DF = D_{\rho,mean}K^{\psi} \tag{2}$$

355   *K* and ψ in Equation (2) can be calculated using Equation (3) and Equation(4).

356
$$K = \frac{D_{\rho,min}}{D_{\rho,mean}} \ (-) \tag{3}$$

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

360
$$\psi = \frac{2D_w - T_d}{T_d - 2} \ (-) \tag{4}$$

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

363   The resulting DF also influences the peripheral wall structures. Figures 6 and 7 have documented
364 the results of the DF and illumination for alternative wall thicknesses of 300 mm and 100 mm in the
365 3D space in the plan view and in the section.
366   The daylight and DF were measured in several production halls. This article shows two case
367 studies. When analyzing the proportion of the glazed area (windows in the vertical plane) to the floor
368 area, this proportion varies from 3%–6% in halls with a large floor area.
369   Based on this analysis, we can also calculate the DF relationship in this case, which uses the
370 percentage of glazing P:

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

372   We can express daylight factor as:

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

374 where

375   A_W Area of the window structures (m²).
376   A_F Area of the floor (m²).
377   B can be calculated by:

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

379   In this study, we reviewed and analysed the effectiveness and adequacy of daylight that forms
380 the basis for the application of integral light. A case study was conducted in two large industrial
381 buildings to get a picture of the state of the environment and the ability to meet the relevant
382 standards. As mentioned in the accompanying lighting application, there is a prescription—a standard
383 in the Czech Republic that prescribes the minimal indoor climate requirements for minimum daylight
384 (Figure 2). Emphasis has therefore been put on the use of daylight to increase the visual comfort of the
385 industrial hall during the day and thus the possibility of saving energy on artificial light. We have
386 noticed that daylighting in the tested knitting hall of a textile factory does not meet the required
387 conditions throughout the work area. The hall is used during the day, where there are pleated
388 machines that are utilised by the workers. At points and places where the values are lower than the
389 required illumination size, artificial lighting such as electric lights is needed to supplement the
390 daylight to reach the desired levels. The overall situation is particularly interesting in terms of visual
391 perception.
392 The lights that run during the daytime in hall F are closer to the windows and two times higher than
393 in the hall G. Daily light was measured when artificial light sources were switched off.

4. Conclusions

395   Our task was to evaluate the daylight lighting in selected areas of the textile factory located in the
396 east part of Slovakia. After performing preliminary calculations, following in situ measurements, and
397 modelling and calculations using simulation programs, the following can be stated. A common
398 parameter for daylight saving is the DF factor (daylight factor) in many countries. The daylight level
399 measurement is relatively complicated because the level of outdoor lighting may change during the
400 day. Finding a suitable day when acceptable conditions are met is difficult. Although the criteria are
401 met and the outdoor lighting is within the allowed range, it may change during the measurement.
402 Especially when there are a lot of control points. In our case study, we wanted to show how this task
403 can be done. In the ordinary interior of the residential buildings, it is easier because the space is
404 relatively small. In industrial buildings, the interiors are large in size. Sometimes the production halls
405 are above and the upper daylight (skylights) can only be applied in the floor under the roof. On the

406 lower floors, it is possible to modify the structures or use the light pipe. When using windows only (as
407 is this case), there is a significant drop in the DF.
408   In this case, the hall was an industrially operating hall that measured 54 metres x 54 meters with
409 a height of about 5 meters. This type of 'hall' can also be compared with large spaces in other
410 buildings (not only industrial). Such spaces are also typical for administrative and other buildings
411 where there is a free arrangement without built-in partitions. In this study, a simple relationship to
412 predict the level of daylight was derived, depending on the area of the windows. This relationship can
413 be used to predict the size of glazed parts in the outer wall in the given areas. Since the daylight-
414 protected windows are inadequate, it is necessary to bring light to other distances in a different way.
415 As we know, daylight is at least physiologically and psychologically necessary. The person inside
416 must feel the connection between the enclosed interior and the exterior. This is sometimes only a
417 visual idea that cannot be mathematically described. Therefore, the need for daylight in the conditions
418 we described is necessary if the daily factor DF is a low value.
419   The calculations that we have performed and confronted with the measurements in a real
420 industrial operation are presented in this case study of large spaces. It should be emphasized that the
421 results are different if we take into account the normative boundary conditions than when calculating
422 using the simulation program. These are also differences when considering a furnished and
423 unfurnished interior. Any situation of preliminary determination of equipment and built-in elements
424 in the interior will be represented by other conditions and only the calculated results will be
425 indicative. They come closer to the values we can expect in a real interior.
426   The contribution shows the possibility of DF approximation when using windows. In residential
427 buildings, the windows are approximately 10% of the floor area. In an industrial setting, especially in
428 industrial buildings or other large-spaced indoor areas, it is about 3%–6%. For the preliminary
429 determination of DF in such cases, Equation (6) can be used.
430   When assessing building sustainability based on computational programs, the daylight element
431 becomes just one of the sustainability assessment indicators. At the same time, the need for daylight is
432 essential for sustainability and its emphasis should be highlighted in evaluation programs. Of course,
433 it is not a simple matter to find a compromise between ecology, environment, economics, and energy
434 requirements. However, this is the role for all of us in the future, because getting closer to sustainable
435 development is our goal.

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440 draft. Erika Dolníková conducted measurements of illuminations. Bystrík Dolník established a model for
441 simulation and conducted daylight simulations using the simulation computer program. Dušan Katunský, Erika
442 Dolníková, and Bystrík Dolník jointly performed analysis of the data and discussed the issues. Dušan Katunský
443 developed the computational model and wrote the final version of the study.

444 **Conflicts of Interest:** The authors declare no conflicts of interest.

References

446 1.   Kontadakis, A.; Tsangrassoulis, A.; Doulos, L.; Topalis, F. An active sunlight redirection system for daylight
447   enhancement beyond the perimeter zone, *Building and Environment* **2017**, 113,
448 2.   Tsangrassoulis, A.; Doulos, L.; Santamouris, M.; Fontoynont, M.; Maamari, F.; Wilson, M.; Jacobs, A. ;
449   Solomon, J.; Zimmerman, A.; Pohl, W.; Mihalakakou, G. On the energy efficiency of a prototype hybrid
450   daylighting system, *Solar Energy* **2005**, 79, 1
451 3.   Doulos, L.T.; Tsangrassoulis, A.; Kontaxis, P.A.; Kontadakis, A.; Topalis, F.V. Harvesting daylight with LED
452   or T5 fluorescent lamps? The role of dimming, *Energy and Buildings* **2017**, 140
453 4.   Doulos, L.; Tsangrassoulis A.; and Topalis, F. The role of spectral response of photosensors in daylight
454   responsive systems, *Energy and Buildings* **2008**, 40

455 5.   Bellia, L., Fragliasso, F., & Stefanizzi, E. Why are daylight-linked controls (DLCs) not so spread? A literature
456   review. *Building and Environment* **2016**, *106*, 301-312.
457 6.   Bellia, L., Pedace, A., & Fragliasso, F. The impact of the software's choice on dynamic daylight simulations'
458   results: A comparison between daysim and 3ds max design®. *Solar Energy* **2015**, *122*, 249-263.
459 7.   Shishegar, N.; Boubekri, M. Natural light and productivity: Analyzing the impacts of daylighting on
460   students' and workers' health and alertness. In Proceedings of the International Conference on "Health,
461   Biological and Life Science" (HBLS-16), Istanbul, Turkey, 18–19 April **2016**.
462 8.   Friborg, O.; Rosenvinge, J.; Wynn, R.; Gradisar, M. Sleep timing, phonotype, mood, and behavior at an arctic
463   latitude (69°N). *Sleep Med.* **2014**, 15, 798–807.
464 9.   McColl, S. L.; & Wilkinson, F. Visual contrast gain control in migraine: Measures of visual cortical
465   excitability and inhibition. *Cephalalgia* **2000**, *20*(2), 74.
466 10. Smolders, K.C.H.J.; De Kort, Y.A.W. & Cluitmans, P.J.M. Higher light intensity induces modulations in brain
467   activity even during regular daytime working hours. *Lighting Research and Technology* **2015**, *48*(4), 433-448.
468 11. Yao, J.; Chow, D.H.C.; Chi, Y.-W. Impact of Manually Controlled Solar Shades on Indoor Visual Comfort.
469   *Sustainability* **2016**, *8*, 727.
470 12. Fabi, V.; Andersen, R. K.; & Corgnati, S. Verification of stochastic behavioural models of occupants'
471   interactions with windows in residential buildings. *Building and Environment* **2015**, *94*(P1), 371-383.
472 13. Gou, Z.; Lau, S.S.; Ye, H. Visual alliesthesia: The gap between comfortable and stimulating illuminance
473   settings. *Build. Environ*. **2014**, 82, 42–49.
474 14. Gou, Z.; Lau, S.S.; Qian, F. Comparison of mood and task performance in naturally-lit and artificially-lit
475   environments. *Indoor Built Environ.* **2015**, 24, 27–36.
476 15. Amundadottir, M. L., Lockley, S. W., & Andersen, M. Unified framework to evaluate non-visual spectral
477   effectiveness of light for human health. *Lighting Research and Technology* **2017**, *49*(6), 673-696.
478 16. Lee, J.H.; Moon, J.W.; Kim, S. Analysis of occupants' visual perception to refine indoor lighting environment
479   for office tasks. *Energies* **2014**, 7, 4116–4139.
480 17. Wang, N.; Boubekri, M. Design recommendations based on cognitive, mood and preference assessments in a
481   sunlit workspace. *Lighting Research and Technology* **2011**, 43, 55–72.
482 18. Yokoya, M.; Yamamoto, S.; Yamauchi, Y.; Yamamoto, S.; Ouda, O.; Nakaguchi, T.; & Tsumura, N. Subjective
483   evaluation of specular appearance for multiple observations using projector-based appearance reproduction
484   Vol. 6626 LNCS, *3rd International Workshop on Computational Color Imaging, CCIW* **2011**; Milan; Italy;
485 19. Lee, K.S.; Han, K.J.; Lee, J.W. Feasibility Study on Parametric Optimization of Daylighting in Building
486   Shading Design. *Sustainability* **2016**, *8*, 1220.
487 20. Hirning, M.B.; Isoardi, G.L.; & Cowling, I. Discomfort glare in open plan green buildings. *Energy and*
488   *Buildings* **2014**, 70, 427–440.
489 21. Hirning, M.; Coyne, S.; & Cowling, I. The use of luminance mapping in developing discomfort glare
490   research, *Journal of Light and Visual Environment* **2010**, *34*(2), 101-104.
491 22. Shen, H.; Tzempelikos, A. Daylight-linked synchronized shading operation using simplified model-based
492   control; *Energy and Buildings* **2017**, (145), 200-212.
493 23. Švajlenka, J.; Kozlovská, M.; Pošiváková, T.; Čonková, E. Indoor Analysis of Environment in Buildings.
494   *Chemické Listy* **2017**, 111, 398-403.
495 24. Švajlenka, J.; Kozlovská, M.; Pošiváková, T. Assessment and biomonitoring indoor environment of
496   buildings. *International Journal of Environmental Health Research* **2017**, 27, 427-439.
497 25. Baker, N. & Steemers, K.; *Daylight Design of Buildings: A Handbook for Architects and Engineers*, Book
498   Routledge **2014**, ISBN 978-1134-257-348, 260 pgs.
499 26. Lyons, L. S. *Handbook of Industrial Lighting,* Elsevier **2013**, ISBN 0-408-00525-4, 224 pgs.
500 27. Dolníková, E. & Katunský, D. *Hodnotenie svetelnej pohody pri kombinovanom osvetľovacom systéme v*
501   *priemyselných halách*, TUKE Košice **2017**, ISBN 978-80-553-2809-6, 151 pgs.
502 28. Kalousek, M. & Mohelníková, J. Influence of Window on Solar Gains and Daylight Level, *Advanced Materials*
503   *Research* **2014**, Vol. 1041, pp. 175-179.
504 29. Ferencikova, M. & Darula, S. Availability of daylighting in school operating time; *Light and Engineering* **2017**,
505   25 (2), 71-78.
506 30. Moazzeni, M.H.; Ghiabaklou, Z. Investigating the influence of light shelf geometry parameters on daylight
507   performance and visual comfort, a case study of educational space in Tehran, Iran. *Buildings* **2016**, 6, 26.

508   31.   Krüger, E. L., & Fonseca, S. D. Evaluating daylighting potential and energy efficiency in a classroom
509   building, *Journal of Renewable and Sustainable Energy* **2011**, *3*(6).
510   32.   Piderit Moreno, M.B.; Labarca, C.Y. Methodology for assessing daylighting design strategies in classroom
511   with a climate-based method. *Sustainability* **2015**, 7, 880–897.
512   33.   Xue, P.; Mak, C.M.; Huang, Y. Quantification of luminous comfort with dynamic daylight metrics in
513   residential buildings. *Energy Build.* **2016**, 117, 99–108.
514   34.   Nebia, B.; Tabet Aoul, K. Overheating and Daylighting; Assessment Tool in Early Design of London's High-
515   Rise Residential Buildings. *Sustainability* 2017, *9*, 1544.
516   35.   Iringova, A. Impact of external shading on light comfort and energy efficiency in apartment buildings. *Appl.*
517   *Mech. Mater.* **2017**, 861, 485–492.
518   36.   Mohsenin, M.; Hu, J. Assessing daylight performance in atrium buildings by using Climate Based Daylight
519   Modeling. *Solar Energy* **2015**, 119, 553–560.
520   37.   Berardi, U.; Anaraki, H.K. The benefits of light shelves over the daylight illuminance in office buildings in
521   Toronto. *Indoor Built Environ.* **2016**, 1–19.
522   38.   Gonzalez, J.; Fiorito, F. Daylight design of office buildings: Optimisation of external solar shadings by using
523   combined simulation methods. *Buildings* **2015**, 5, 560–580.
524   39.   Pellegrino, A.; Cammarano, S.; Verso, V.R.; Corrado, V. Impact of daylighting on total energy use in offices
525   of varying architectural features in Italy: Results from a parametric study. Build. Environ. 2017, 113, 151–162.
526   40.   Costanzo, V.; Donn, M. Thermal and visual comfort assessment of natural ventilated office buildings in
527   Europe and North America. *Energy Build.* **2017**, 140, 210–223.
528   41.   Konis, K. Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office
529   building in San Francisco, California. *Build. Environ.* **2013**, 59, 662–677.
530   42.   Mistrick, R.; Casey, C.; Chen, L.; Sarith Subramaniam, S. Computer modeling of daylight-integrated
531   photocontrol of electric lighting systems. *Buildings* **2015**, 5, 449–466.
532   43.   Nasrollahi, N.; Shokri, E. Daylight illuminance in urban environments for visual comfort and energy
533   performance. *Renew. Sustain. Energy Rev.* **2016**, 66, 861–874.
534   44.   Reinhart, C.F.; Wienold, J. The daylighting dashboard—A simulation-based design analysis for daylit
535   spaces. *Build. Environ.* **2011**, 46, 386–396.
536   45.   Amorim, R.; López, J.C.; Molina-Moreno, V.; Peña-García, A. Use of Natural Light vs. Cold LED Lighting in
537   Installations for the Recovery of Victims of Gender Violence: Impact on Energy Consumption and Victims'
538   Recovery. *Sustainability* **2017**, *9*, 562.
539   46.   Shen, E.; Hu, J.; Patel, M. Energy and visual comfort analysis of lighting and daylight control strategies.
540   *Build. Environ.* **2014**, 78, 155–170.
541   47.   Uriarte, U.; Hernández, R.J.; Zamora, J.L.; Isalgue, A. Side-view atmospheres under outdoor midday high
542   luminance. *Buildings* **2016**, 6, 53.
543   48.   Gunay, H.B.; O'Brien, W.; Beausoleil-Morrison, I.; Gilani, S. Development and implementation of an
544   adaptive lighting and blinds control algorithm. *Build. Environ.* **2017**, 113, 185–199.
545   49.   Jia, L.; Afshari, S.; Mishra, S.; Radke, R.J. Simulation for pre-visualizing and tuning lighting controller
546   behavior. *Energy Build.* **2014**, 70, 287–302.
547   50.   Doulos, L.; Tsangrassoulis, A.; and Topalis, F. Multi-criteria decision analysis to select the optimum position
548   and proper field of view of a photosensor, *Energy Conversion and Management* **2014**, 86
549   51.   Doulos, L.; Tsangrassoulis A.; and Topalis, F. Quantifying energy savings in daylight responsive systems:
550   The role of dimming electronic ballasts, *Energy and Buildings* **2008**, 40
551   52.   Veitch, J.A.; Whitehead, L.A.; Mossman, M.; & Pilditch, T.D. Chromaticity-matched but spectrally different
552   light source effects on simple and complex color judgments *Color Research and Application* **2014**, *39*(3).
553   53.   Perez, R.; Seals, R.; Michalsky, J. All weather model for sky luminance distribution—Preliminary
554   configuration and validation. *Solar Energy* **1993**, 50, 235–245.
555   54.   Igawa, N.; Koga, Y.; Matsuzawa, T.; Nakamura, H. Models of sky radiance distribution and sky luminance
556   distribution. *Solar Energy* **2004**, 77, 137–157.
557   55.   Katunský, D. Aproximatívny výpočet minimálnych činiteľov dennej osvetlenosti vo veľkorozmerových
558   priemyslových halách. *Building Research Journal* **1992** (40), 299-311.
559   56.   Van Bommel, W.J.M.; van den Beld, G.J. Lighting for work: A review of visual and biological effects. *Lighting*
560   *Res. Technol.* **2004**, 36, 255–269.

561   57.   Yan, B.; Long, E.; Meng, X.; Zhang, Y.; Hou, D.; & Du, X. Influence of user behavior on unsatisfactory indoor
562   thermal environment. *Energy Convers. Manag.* **2014**, 86, 1–7.

563   58.   Sokol, N.; Martyniuk-Peczek, J. *The review of the selected challenges for an incorporation of daylight assessment*
564   *methods into urban planning in Poland.* Proc. Eng. 2016, 161, 2191–2197.

565   59.   Chen, K.W.; Norford, L. Evaluating Urban Forms for Comparison Studies in the Massing Design Stage.
566   *Sustainability* **2017**, (9), 987.

567   60.   Labat, M.; Attonaty, K. Numerical estimation and sensitivity analysis of the energy demand for six
568   industrial buildings in France; *Journal of Building Performance Simulation* **2017**, 3, 1-21.

569   61.   Gourlis, G.; Ivacic, I. A study on building performance analysis for energy retrofit of existing industrial
570   facilities. *Applied Energy* **2016**, 184, 1389-1399.

571   62.   Pham, K.; Garcia-Hansen, V.; Isoardi G. Appraisal of the Visual Environment in an Industrial Factory: a
572   Case Study in Subtropical Climates, Solarlits; *Journal of Daylighting* **2016**, Vol. 3, (2), 12-26.

573   63.   Alarcon, B.; Aguado, A.; Manga, R.; Josa, A.; A value function for assessing sustainability application to
574   industrial buildings. *Sustainability* **2011**, 3, 35–50.

575   64.   Katunsky, D.; Dolnikova, E.; Doroudiani, S. Integrated Lighting Efficiency Analysis in Large Industrial
576   Buildings to Enhance Indoor Environmental Quality. *Buildings* **2017**, 7, 47.

577   65.   Lombera, J.T.; Rojo, J.C. Industrial building design stage based on a system approach to their environmental
578   sustainability. *Construct. Build. Mater.* **2010**, 24, 438–447.

579   66.   Lombera, J-T.S-J; Aprea, I.G. A system approach to the environmental analysis of industrial buildings.
580   *Building and Environment* **2010**, 45, 673–683.

581   67.   *Integral Lighting*, ČSN 360020; CZ Office of Standards, Metrology and Testing Prague, Czech Republic, **2015**.

582   68.   STN 730580; *Daylighting in buildings, Part–1 Basic requirements,* 1986 *Part–2; Daylighting of residential buildings,*
583   2000, Slovak Republic Office of Standards, Metrology and Testing: Bratislava, Slovakia; **2000**

584   69.   EN 12464-1:2012. *Light and Lighting; Lighting of Work Places-Part 1: Indoor Work Places*; Slovak Republic Office
585   of Standards, Metrology and Testing: Bratislava, Slovakia, **2012**

586   70.   CEN/TC 169 07/**2017** *Daylight in buildings* (TC 169 WI 00169068), **2017**

587   71.   International Energy Agency (IEA) *Solar and Heating Cooling Program*, Task 31—*Daylighting Buildings in the*
588   *21st Century.* Available online: http://task31.iea-shc.org/ (accessed on 2 May **2017**).