



[8] 2020 8[1]

АГГ+ часопис за архитектуру, грађевинарство, геодезију и сродне научне области
ACEG+ Journal for Architecture, Civil Engineering, Geodesy and other related scientific fields

008-018

Оригинални научни рад | Original scientific paper

UDK | UDC 72.036(497.15 Бања Лука)"1878/1918"

DOI 10.7251/AGGPLUS2008008A

Рад примљен | Paper received 03/11/2020

Рад прихваћен | Paper accepted 02/12/2020

Biljana Antunović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, biljana.antunovic@aggf.unibl.org

Miroslav Malinović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, miroslav.malinovic@aggf.unibl.org

Jelena Rašović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, jelena.rasovic@aggf.unibl.org

Stefan Petrović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, stefan.petrovic@student.aggf.unibl.org

ДНЕВНА СВЈЕТЛОСТ У
ЗГРАДИ АУСТРОУГАРСКОГ
ГРАДИТЕЉСКОГ НАСЉЕЂА

DAYLIGHT PERFORMANCE
IN AN AUSTRO-
HUNGARIAN HERITAGE
BUILDING

Оригинални научни рад

Original scientific paper

Рад прихваћен | Paper accepted

02/12/2020

UDK | UDC

72.036(497.15 Бања Лука)"1878/1918"

DOI

10.7251/AGGPLUS2008008A

Biljana Antunović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, biljana.antunovic@aggf.unibl.org

Miroslav Malinović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, miroslav.malinovic@aggf.unibl.org

Jelena Rašović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, jelena.rasovic@aggf.unibl.org

Stefan Petrović

University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bulevar Vojvode Stepe Stepanovića 77/3, stefan.petrovic@student.aggf.unibl.org

ДНЕВНА СВЈЕТЛОСТ У ЗГРАДИ АУСТРОУГАРСКОГ ГРАДИТЕЉСКОГ НАСЉЕЂА

РЕЗИМЕ

Циљ овог рада јесте истраживање перформанси дневне свјетлости у згради аустроугарског градитељског наслеђа која се налази у Бањој Луци, Босна и Херцеговина. Зграда је првобитно коришћена као војни штаб, а касније је пренамијењена за административне и образовне функције. Мјерење дневне свјетлости извршено је у репрезентативној просторији-канцеларији зграде. Резултати мјерења су анализирани са аспекта међународних стандарда и у односу на специфичну архитектуру зграде. Такође је урађена симулација дневне свјетлости кориштењем софтвера *Design Builder*.

Кључне ријечи: дневна свјетлост, зграде културне баштине, визуелни комфор, симулација

DAYLIGHT PERFORMANCE IN AN AUSTRO-HUNGARIAN HERITAGE BUILDING

ABSTRACT

The aim of this paper is to investigate the daylight performance in an Austro-Hungarian heritage building located in Banja Luka, Bosnia and Herzegovina. The building was originally used as a military headquarters and was later reused for administration and educational functions. The measurement of daylight was performed in a representative room-office in the building. The measurement results are discussed with respect to international standards and in relation to the specific architecture of the building. Furthermore, the simulation of the daylight performance was performed by using the Design Builder software.

Key words: daylight performance, heritage buildings, visual comfort, simulation

1. INTRODUCTION

Light plays an essential role in people's everyday lives and work since humans receive more than 80 % of all information through the sense of sight. The quality of light affects people's health, work efficiency and comfort. Furthermore, daylight is of special importance as humans are, through evolution, adapted to natural light. How much daylight reaches inside a building depends on the building's architecture, the amount and direction of sunlight, cloud coverage, local topography etc. resulting in a certain visual comfort of users. Visual comfort is related to physical quantities such as the illuminance, uniformity, and daylight factor. The recommended values of these photometric quantities for different workplaces are defined in international standards.

The human perception of light is determined by the amount of radiation energy entering the eye and the spectrum of this light. The direct effects of sunlight are related to the chemical reactions it causes in the body, while the indirect effects are related to basic biological functions. A feeling of pleasure and comfort is a complex notion that includes the human psychological experience of space in addition to its physiological needs. It has been shown that productivity at work increases with comfortable and pleasant spaces and that is why the light comfort has been taken into consideration. Moreover, improving the visual performance of employees results in a higher alertness level that can reduce errors and accident rates [1,2] while inadequate light will influence work efficiency as well as our health and personal wellbeing.

Since the intensity of daylight has been variable and daylight will not be always and everywhere sufficient to carry out daily tasks, the artificial light must be used. For many buildings, the best option is using daylighting and electric lighting together, with an appropriate lighting control during the daytime [3]. This method is the most efficient and involves replacing classic incandescent lighting with automatic halogen, fluorescent or LED lighting.

Daylight plays an important role in the building sustainability involving the design of energy-efficient buildings while maximizing the use of daylight. For example, an examination of energy consumption in one year reveals that the artificial light accounts for around 19% of the total generated electricity while energy consumption of buildings covers about 40% of the total energy consumption in Europe [4]. In some types of buildings, such as office blocks, 10% to 30% of the primary energy is used by lighting. Apart from economic reasons and energy-related CO₂ emissions, natural light utilization has to be at the highest level because the human eyes have adapted best in daylight and people feel more comfortable in the space with natural light. Visual comfort is one of the parameters that determine the quality of the indoor environment, in addition to thermal and acoustic comfort as well as the air quality.

Before reconstructing an existing integrated lighting system or designing a new one, it is necessary first to carry out all the appropriate analyses. The availability and quality of natural lighting in a room and daylight performance of buildings can be evaluated by appropriate physical quantities. The light characteristics of an object are the illuminance, brightness, illuminance uniformity, daylight factor, annual light exposure and direct normal radiance. In the case of the daylight analysis, the most important are the illuminance and daylight factor. The illuminance values are usually taken into account at the working plane level.

2. PHYSICAL QUANTITIES

Daylight consists of three components: direct light from the Sun, light diffused from the sky and light reflected from the surrounding. Direct sunlight is characterized by a very high intensity and constant movement, while diffused skylight is characterized by sunlight scattered by the atmosphere and clouds [5]. Light (sunlight and skylight) which comes from the ground, neighboring buildings, vegetation, trees, and reaches the observed points, determines the reflected light component [5].

The final value of daylight is obtained as a sum of three components. Depending on sun paths and the sky condition, daylight varies significantly with the time of the day and season. The most important physical quantities used to describe light comfort are the illuminance and daylight factor (DF).

The flux light ϕ received on the surface S is named the illuminance:

$$E = \frac{\phi}{S} \quad (1)$$

Illuminance is expressed in lux (lx). It can be measured with a lux meter or predicted by a computer simulation. Task characteristics and the visual environment are properties that determine the needed values of illuminance.

For example, the UK recommendation for working plane illuminance is 300 lx for computer-based work and 500 lx for paper-based work. The standard EN BAS 12464 defines 500 lx for the office working plane (Table 1).

The daylight factor is the measure that represents the amount of daylight that reaches inside the room relative to the amount of unobstructed daylight available outside, under a cloudy sky condition:

$$DF = \frac{E}{E_o} \cdot 100 \quad (2)$$

DF is expressed in percents.

The higher value of DF indicates better daylight conditions inside a building. The location, sky condition, time of the year, room and window size, roof, wall thickness and the situation of the room (design and furniture) are the parameters influencing the value of DF. It is used to determine what impact the geometry of the space, location and amount of fenestration have on daylight penetration as well as an important parameter in the energy-efficient building designs. A minimum average daylight factor of 1% is required for support spaces, 1.5% for living spaces and 2% for work spaces, with a minimum of 75% of the observed plane areas [6]. To ensure that rooms in dwellings and in most other buildings have a predominantly daylight appearance, the average daylight factor should be at least 2%. If the average daylight factor in a space is between 2% and 5%, supplementary electric lighting is usually required [3]. Average DF which is greater or equal to 5% is considered as strong and in that case electric lighting will not be used during daytime.

The quantitative analysis of daylight implies the determination of illuminance and the daylight factor. The quality of daylight is associated with its uniform distribution across the indoor area. Lighting uniformity is the ratio of minimum illuminance to average illuminance on a surface:

$$U_0 = \frac{E_{\min}}{E_{av}} \quad (3)$$

The uniformity of illuminance should be set in a range 0.5-0.8. There are two cases when it is considered inadequate: a) the largest part of a working plane (usually more than 20%) is positioned behind the no-sky line; or b) in the room where windows are on one wall the depth of the room is too large with respect to the height and the width of the windows [3]. According to the recommendations, the ratio between the illuminance of a working plane and surrounding space should not exceed 3:1.

Table 1. Requirements for different offices, tasks and activities (EN BAS 12464)[7]

| Offices | | |
|----------|---|----------------------|
| Ref. No. | Type of interior, task or activity | E _{av} (lx) |
| 1. | Filing, copying, etc. | 300 |
| 2. | Writing, typing, reading, data processing | 500 |
| 3. | Technical drawing | 750 |
| 4. | CAD workstations | 500 |
| 5. | Conference and meeting rooms | 500 |
| 6. | Reception desk | 300 |
| 7. | Archives | 200 |

3. THE ARCHITECTURE AND DEVELOPMENT OF PRESENT-DAY RECTORATE BUILDING

The present-day Rectorate building of the University of Banja Luka is located within the historical military campus, which dates back to the Ottoman time in Banja Luka (1528-1878). Its current position corresponds to the urban part of Banja Luka, named Borik – during the Turkish time the swampy outskirts of the sparsely populated area. It is rather unknown when exactly the first military facility was erected at the site, but for sure, the fairly large Ottoman campus had already existed in 1863, which could be seen in the map from the period before the Austro-Hungarian regiment (1878-1918) [8]. Because of the military background of the site, that was retained until 2001, the historical archival records, especially about construction activities, are not available for public research.

Within the analysis based on the comparative method, as well as the examination of used materials in the complex, like reinforced concrete, Austrian-size bricks, cement mortar etc., it can be presumed, with a high level of certainty, that the Austro-Hungarian army rebuilt the complex and formed it according to general guidelines for contemporary military facilities [10]. It still remains unclear which of the old Turkish buildings were retained, if any were at all at that time, yet it is known that the campus was for sure the home for infantry and artillery garrisons of the Ottoman troops [11].

Again, the exact time of the complex reconstruction is unknown, but its position had been already noted in a so-called “Austrian map”, a map that indicated the existing and planned buildings as well as buildings to be demolished in the period 1880-1884 (Figure 1).

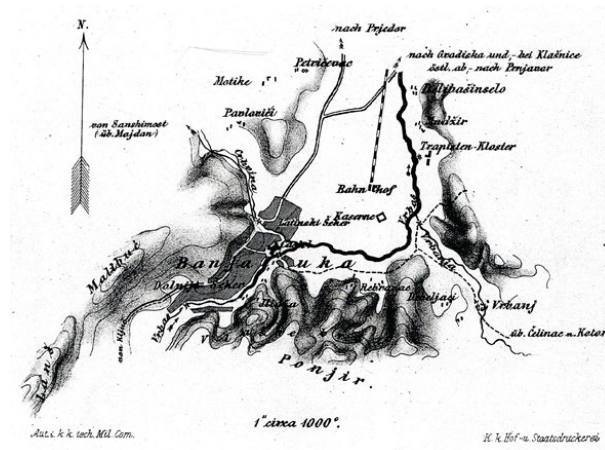


Figure 1. Banja Luka and its surroundings on one of the Austrian maps dated in 1863. This map edition is issued 1863 in “Wiener Zoll” scale, dimensions 24x20cm [9]

In favour of that there are other facts, cross-referenced to construction activities on the surrounding military facilities, like the Military hospital complex, located in the present-day Mladen Stojanović Park situated northern from the Campus, with the Monument to fallen soldiers, and the central Military Headquarters, western from the site, all built in the first years of the Austro-Hungarian rule [8].

It is important to understand two significant local, territorial settings in order to properly perceive the present-day Rectorate building location and orientation. The first is the site of the Military Authorities’ Headquarters (Militärämtesgebäude Ger.) which was built in 1879, on one of the most prominent cross-roads at the time: the main street oriented north-south, Kaiserstraße, and the former Street of Banja Luka Field, oriented east-west, heading to the Vrbas River with the Military campus Vrbas on its left bank (Figure 2). The second setting is the orientation and treatment of the Street of Banja Luka Field, today the Alley of Saint Sava, which at the time received a rich tree alley and prominently linked the military headquarters and the Campus. The alley is perfectly aligned with the Campus orthogonal disposition, with a dominating central building, the subject of this paper, set at the end of it so it prominently marks the end of the alley [8]. As it can be seen in the historical photos dated in 1908 [12], the central building was situated with its longer axis orthogonally to the tree alley, exactly as the present-day Rectorate stands. Since significant military constructions by foreign authorities were not recorded in years prior and obviously during the World War I, it can be assumed that the main building in its full shape and extent was built as an extension, less possibly a completely new construction on the place of the former central building during the Kingdom of Serbs, Croats and Slovenes, later the Kingdom of Yugoslavia.



Figure 2. Military campus Vrba. View of the entrance alley; postcard issued in 1908 [12]

The present-day Rectorate building (Figure 3) corresponds to a typical office or residential building from the early XX century built in countries with the Austro-Hungarian legacy – many similar buildings with the functions of convents, railway stations, schools etc. can be found around the former Empire, dated either during or shortly after the Austro-Hungarian era. It has a strongly emphasized longitudinal axis, oriented north-south, divided into five partitions: central and side Avant-Corps, all interconnected with side wings. In structure, it has a slightly elevated ground floor with two floors above, and a basement only below the central part and side wings. The main corridor is located on the eastern façade, with the office rooms on the west, facing the aforementioned tree alley, almost entirely flanking the façade and significantly obstructing the sunlight.



Figure 3. View of the western façade with the main entrance to the Rectorate building. The examined room is the uppermost right in the view, as indicated on the image.

4. MEASUREMENT METHODOLOGY

The examined room is located in the southern wing, next to the central corps, on the second floor. It is oriented to the west, with an administrative function and usual furnishing displacement. The floor plane of the 2nd floor and the indication of the examined office are shown in Figure 4. Since the position of the measured point is defined by the working plane position, it wasn't necessary to create a grid of measured points over the entire room. The working plane is at 0.85 m height above the floor. The illuminance values, measured during the same hour of different days, are compared with the Standard and to each other. As it can be

seen from the figure, the window of the examined room is dislocated with respect to the center of the external wall and it is in the corner of the wall whose thickness is around 0.5 m limiting the angle of daylight incidence in the room. Also, the ratio of the window surface to the floor surface is approximately 1/7.

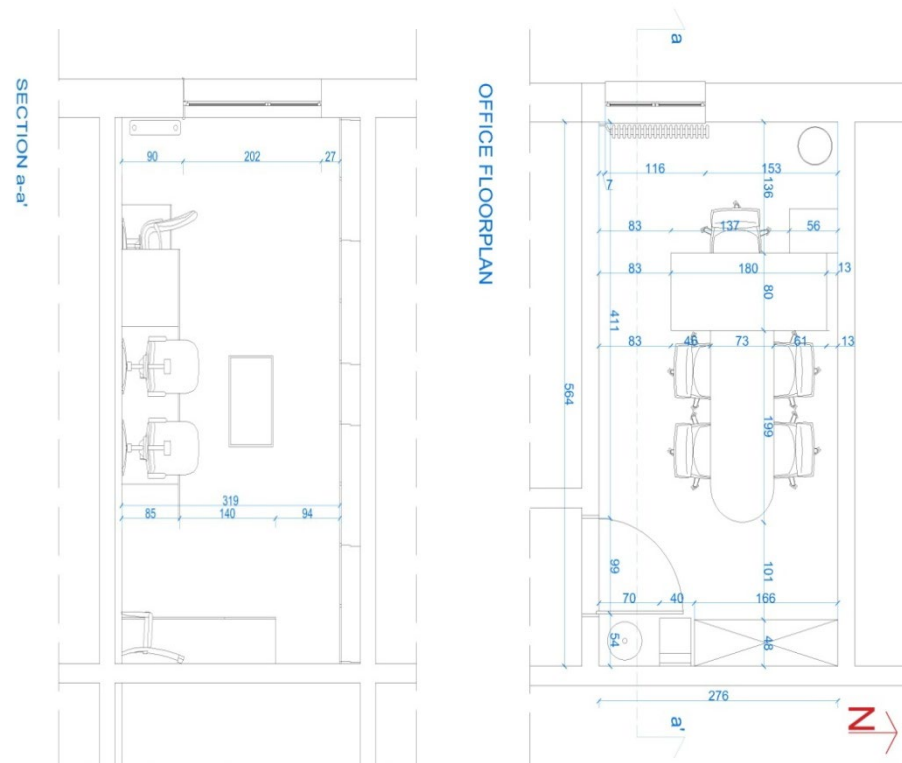


Figure 4. Floor plan and the longitudinal section view of the 2nd floor with the indication of the examined office, present conditions

For the purpose of the illuminance measurement, which is performed according to the standard EN BAS 12464, the data logger Almemo Ahlborn 2690-8 and corresponding sensor-luxmeter were used (Figure 5). Technical specifications of the instrument are: the illuminance measurement range (0 lx to 260.000 lx), accuracy $\pm 5\%$ (optional $< 3\%$) and spectral correction.



Figure 5. Almemo Ahlborn 2690-8 (left), luxmeter (right)

5. RESULTS

The results of the daylight measurement are shown in the Table 2. The shown values are averaged around the given hours at 9 a.m., noon and 3 p.m., respectively, for two overcast days in July and August. The average measured illuminance value varied from 31 lx to 263 lx on the first day of measurement (17th July) and from 83 lx to 323 lx on the second day of measurement. The minimum illuminance of 13 lx was measured at 9 a.m. on the first and the maximum value of 438 lx was reached at noon on the second day. Comparing the results of measurement to the prescribed standard values for this type of office, the conclusion is that the average illuminance has to be from 300 lx to 500 lx which is fulfilled only for the value of 323 lx recorded on the second day at noon (Table 2).

The daylight factor was calculated using the Equation 2 shown in Table 2. As it can be seen, DF varies from 0.62% to 5.26% on the first and from 1.66% to 6.46 % on the second day of measurement. The minimum DF of 0.62% was measured at 9 a.m. on the first and the maximum of 6.46% at noon on the second day of data taking. Four out of six measurements fulfill the requirement of minimum DF 2%, while 3 out of those are greater than 5% in which case the room is considered as daylit and no electric lighting during most of the daytime is needed. This is the case for the first day at 3 p.m. 5.26% and two on the second day 5.32 % at 9 a.m. and the maximum value 6.46% taken at noon (Table 2).

Table 2. The measurements of the illuminance and daylight factor

| Date | Time(hour) | $E_{min}(lx)$ | E_{max} $E_{max}(lx)$ | $E_{av}(lx)$ | DF(%) |
|------------|------------|---------------|----------------------------|--------------|-------|
| 17.7.2020. | 09:00 | 13 | 47 | 31 | 0.62 |
| | 12:00 | 80 | 245 | 165 | 3.3 |
| | 15:00 | 180 | 338 | 263 | 5.26 |
| 18.8.2020. | 09:00 | 47 | 331 | 266 | 5.32 |
| | 12:00 | 95 | 438 | 323 | 6.46 |
| | 15:00 | 45 | 347 | 83 | 1.66 |

For the examined room, the illuminance and daylight factor have been simulated using the software Design Builder V 5.5.0.012 [13,14]. As the input for the simulation certain criteria have

been used: the analyzed area is georeferenced on the geographical coordinates of Banja Luka, the altitude of Banja Luka is defined, the Rectorate building was modeled considering the surrounding buildings which could influence its daylight. Furthermore, the office is dimensioned based on the recorded light dimensions and placed at its absolute elevation, the wall thicknesses are dimensioned, the window is with defined dimensions of the glazing and the frame, defined glazing type. Finally, all internal surfaces are assigned their characteristics: material class, roughness, emissivity, solar absorption, etc. The resulting distribution of the simulated daylight is shown in Figure 6 where colors are ranging from the black which corresponds to the darkest, and red to the brightest parts of the working plane.

The simulation has been performed for three eligibility criteria: LEED EQ 8.1 credit, BREEAM Health and Wellbeing Credit HEA 01 and Green Star IEQ4 credit.

LEED Credit EQ 8.1 defines the condition that at least 75% of area in occupied spaces needs to be adequately daylight with the illuminance above the minimum threshold value set at 269.098 lx. This condition failed because only 33.3% of the area meets the requirement.

BREEAM Health and Wellbeing Credit HEA 01 define condition that at least 80% of area is adequately daylight. There are two conditions which must be met at the same time: the minimum threshold value of daylight factor is 2.0% and the uniformity ratio is at least 0.3 or a minimum point daylight factor of 0.8% (spaces with glazed roofs, such as atria, must achieve a uniformity ratio of at least 0.7 or a minimum point daylight factor of at least 1.4%) [13,15]. For the building considered here the obtained average DF is 2.2%, however the minimum DF is 0.61% and uniformity ratio 0.28. That means that the first condition is met and the second one fails.

Green Star Credit IEQ4 performs the calculation based on the percentage of the area **with** the minimum daylight factor: DF at least 2.0%, and daylight Illuminance of at least 250 lx [13]. These criteria are also not met since the minimum DF is 0.61% and the working plane area within the limits is 28%.

Comparing the measurements and simulation of daylight performance, the conclusion is that there is inadequate daylighting during most of the time.

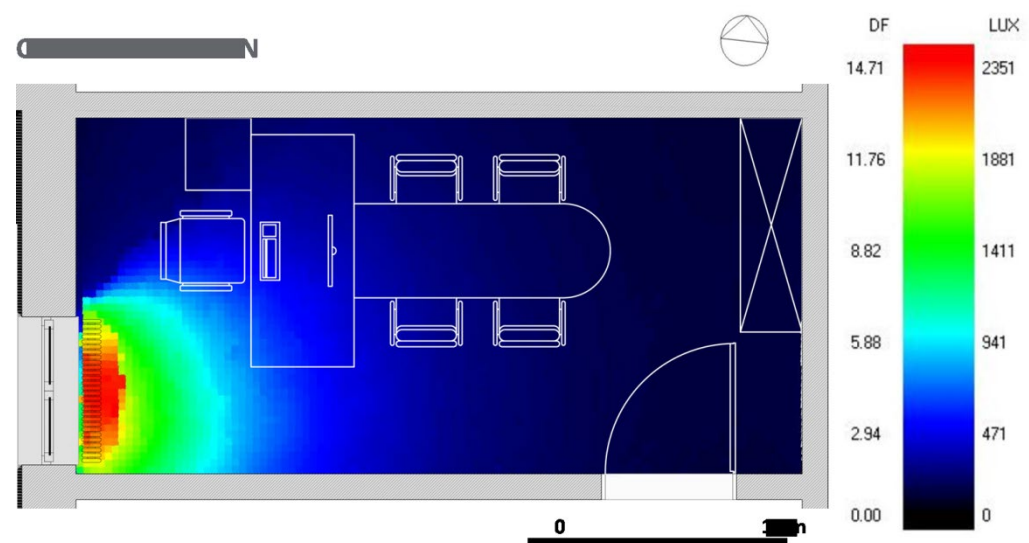


Figure 6. Distribution of the simulated daylight in the examined room

6. CONCLUSION

The measurement and simulation of daylight performance in a representative office of an Austro-Hungarian heritage building located in Banja Luka, Bosnia and Herzegovina has been presented in this paper. Two physical quantities have been used to analyze the daylight performance: the illuminance and the daylight factor. The obtained results of measurement have shown the illuminance and DF vary with time and during the most of the time the criteria prescribed by the standard are not met. The simulation of these two quantities has been done using the Design Builder software for different criteria and none of them is completely satisfied. The conclusion is that daylighting is inadequate. Therefore, the electrical lighting must be used during the day, having a negative impact on the energy efficiency and sustainability of the building.

It is obvious that apart from the room dimensions, the position and the surface of windows have a great impact on the visual comfort in the building as well as the building construction. Since the examined building is a cultural heritage, the next step of investigations is going to be a more detailed analysis of the building, measurements and simulation. Moreover, some specific building parts, like window casings and enclosures, fixtures and glazing need to be properly addressed in order to propose the improvements of the daylight performance while not changing the building elevation view and endangering its historical and ambiental values.

7. BIBLIOGRAPHY

- [1] W.J.M van Bommel, G. J. van den Beld, M.H. F van Ooyen. Industrial lighting and productivity, Philips Lighting, 2002.
- [2] W.J.M van Bommel, G. J. Van den Beld, Lighting for Work: visual and biological effects, Philips Lighting, 2004, tom. 255-269.
- [3] Institution, British Standards. Lighting for buildings, Part 2: Code of practice for daylighting. London: BSi, 2008.
- [4] International Energy Agency. Light's Labour's Lost-Policies for energy-efficient lighting. Paris: IEA Publications, 2006. 2006484568.
- [5] <https://www.velux.com/deic/daylight/daylighting>. [30 January 2020.]
- [6] A. Michaela, S. Gregoriou, S.A. Kalogirou, Environmental Assessment of an Integrated Adaptive System for the Improvement of Indoor Visual Comfort of Existing Buildings. S.I. : Renewable Energy, 2017, T. 115.
- [7] BAS EN 12464-1:2012, Light and lighting. Lighting of work places. Indoor work places
- [8] Malinović, Miroslav. A Monograph: The Architecture in Banja Luka during the Austro-Hungarian rule in Bosnia and Herzegovina (1878-1918). Banja Luka : Faculty of Architecture and Civil Engineering, University of Banja Luka, 2014.
- [9] Austrian National Library. K I 112916,1 Kar. Vienna : Map Department, 1863.
- [10] Bluntfehli, F. Gebäude für Verwaltung, Rechtspflege und Gesetzgebung; Militärbauten. T. 4, Entwerfen, Anlage und Einrichtung der Gebäude, Halbbd. 7. Darmstadt : Diehl, 1887.
- [11] Edmund, Stix. Bosna, Wilāyet, Landesregierung: Das Bauwesen in Bosnien und der Hercegovina. Vienna : Hof- u. Staatsdruckerei, 1887.
- [12] Vicić, Snežana, Vicić, Dragan i Đukić, Milanka. Pozdrav iz Banjaluke, Banjaluka na starim razglednicama. Belgrade : Atelje Vicić, 2006.
- [13] <https://designbuilder.co.uk/> [Dec 10, 2020].

- [14] Zomorodian, Z.S.; Korsavi, S.S.; Tahsildoost, M. The effect of window configuration on daylight performance in classrooms: A field and simulation study. *Int. J. Archit. Eng. Urban Plan* 2016, 26, 15–24
- [15] BNV. *New Construction – Technical Manual*, Norwegian Green Building Council and BRE Global, (SD 5066A: ISSUE 1.1), 2012, pp. 1-397.