Exploring daylighting design optimization and its energy impact in office buildings for different shading systems. Case study: Tirana

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1 ABSTRACT

The focus of this research is the enhancement of daylighting design in office buildings and the lowering of energy consumption. This study systematically explores and analyzes the visual performance of two different prototypical office layouts through the case studies selected in Tirana. The sensitivity of total energy use due to orientation, window area, glazing properties (U-value, visible transmittance), shading system is described.

The research approach is conducted through lighting simulation software and face-to-face questionnaires. For each office building the actual conditions are firstly analyzed, and then, different other options are provided. The findings from this study provide evidence of the problems of daylight and artificial lighting problems and especially workers´ performance difficulties related to lighting conditions. Thus, recommended solutions, which try to optimize daylighting design, to enhance workers´ productivity and to lower energy consumption, are provided.

2 INTRODUCTION

Office work has undergone a lot of radical transformation. With rapid advances in information and communication technologies, today's world of work is a world of computers and networks, workflow and data exchange (Lichtweissen 04). With such a transformation, work in offices has been made easier and managers or supervisors are now more motivated to play attention more to the building and workers performance.

Tirana's work offices have undergone a lot of transformation. Tirana has experienced explosive population and urban growth over the last decades and 23% of total labor force of the country live and work in Tirana (Mici, et al. 2007). Thus, the need for more working places has led to new commercial and office buildings. Nowadays, Tirana is the most important commercial area in the country. The urban fabric of the capital city is made off of different types of commercial buildings. However, it is fact that energy efficiency should be taken into serious consideration. Commercial buildings consume 10 % of the overall energy in Albania (QPZ 2011).

Since office buildings are typically occupied during daylight hours (Ubbelohde 2010), a good daylight design contributes seriously in lowering the energy consumption. However, energy efficient lighting is not the only issue motivating the research.

Light is not only an essential prerequisite and the medium by which we are able to see(Ganslandt and Hofmann 1992),good lighting design aims to create perceptual conditions and orient ourselves safely while promoting a feeling of well-being in a particular environment (Ganslandt and Hofmann 1992). Thus, this study is concentrated in finding the best solution to enhance productivity and to lower energy consumption in office buildings in Albania.

According to the statistical data offered by the report of INSTAT, the consumption of electrical energy from non-residential users has risen by 7.5% in 2010 compared with 2009 (INSTAT 2011). Lighting is a major end use of energy in most non-residential buildings (Selkowitz and Winkelmann

1983). Lighting design strategies should be undertaken thereby to reduce energy consumption. Office buildings have an immediate need in finding renewable energies to provide good lighting.

Such a design strategy would implement the usage of energy-efficient lighting components, controls and systems. But, above all, design must be focused in maximizing and optimizing the usage of daylight.

By emphasizing daylight design advantages the study provides suitable solutions, energy efficient oriented ones.Inone way or another, we have made usage of the sun since the beginning of man’s existence. It is said that the history of architecture is the history of human beings coping with the elements, and different civilizations have applied solar principles according to their own knowledge and belief systems (Boubekri 2008). Daylight is the primary source of light and is not just good for vision, but for health as well. Human vision under daylight conditions is normally better than artificial light, because it is usually present in higher quantities and has better color rendering, enabling us to see things more clearly (Workplaceintelligence 2004). On the other hand, daylight is closely related to our health. It is said; where sunlight goes the doctor does not. Goldblatt and Soames (1923) observed that when a precursor of vitamin D in the skin was irradiated with sunlight or ultraviolet light, a substance equivalent to vitamin D was produced (Boubekri 2008). Thus, daylight stimulates production of vitamin D, an essential element for maintaining a healthy immune system. Lack of daylight in offices has been linked to “sick building” syndrome (Workplaceintelligence 2004). Another close relation with daylight is anxiety and mood of workers. Light acts on the production of cortisol, serotonin and melatonin, three important hormones that affect our internal clock and our mood states (Boubekri 2008). Low levels of seratonin (the daylight hormone) together with a low level of neropinephrinecause depression (Boubekri 2008). The brightness of office light effects alertness, concentration, and task performance. Adjusting the type and quality of light can significantly improve working experience and productivity (Al-Anzi 2009)

Most of buildings have limited possibilities to change the amount of daylight reaching office space, but there are ways to ensure that daylight is used effectively. The incorporation of daylighting in office buildings should provide visual comfort and avoid disturbing effects. Thus, providing the correct level of daylight is not a matter of just window size, but also a serious consideration of controls over negative effects. Daylighting design must meet stringent requirements in terms of illumination level, and glare control (Philips 2004).

Therefore, a major challenge that designers face is to effectively combine the many performance parameters involved in daylighting with aesthetic considerations (Andersen, et al. 2008)

3 METHODOLOGY

The study is held in order to provide efficient and economical solutions in optimizing daylighting in office building. In order to fulfill this aim a crucial role is given to the employees, and optimizing work conditions. In order to supply additional information and to provide a deeper study, in-place observation and survey questionnaires were held.

In-place observations were held to provide more exact information for the input data set needed for the simulation process. During observation process relevant importance was given in defining office room’s materials, distribution of artificial lighting and occupancy. On the other hand, survey questionnaires served to provide information about employees’ perception of the workplace and its influence in work efficiency. Thus, analyzing the survey’s results provides additional information for conducting analysis and simulations.

For the evaluation of the performance control scenarios, by daylight simulation, the Perez All-Weather Sky model is used. This was decided due to the absence of local measurements. The case studies were analyzed by using the Daysim software.

Finally, the comparison is developed as a discussion on the result of the simulation analysis and surveys results. By finding the source problem an appropriate solution is given in the end.

3.1 SURVEY ANALYSIS

The questionnaire prepared consists of twenty questions and it is divided in three main parts. The first section of questions aims to understand the relation of the employee with the workplace, the office, and the level of attachment. The second section of questions is focused on the perception of the workplace from the employees and how efficient they feel in their workplace. Whereas, the third section is composed of more direct questions related to the lighting performance in the office. The questionnaire was submitted to twenty employees to each building.

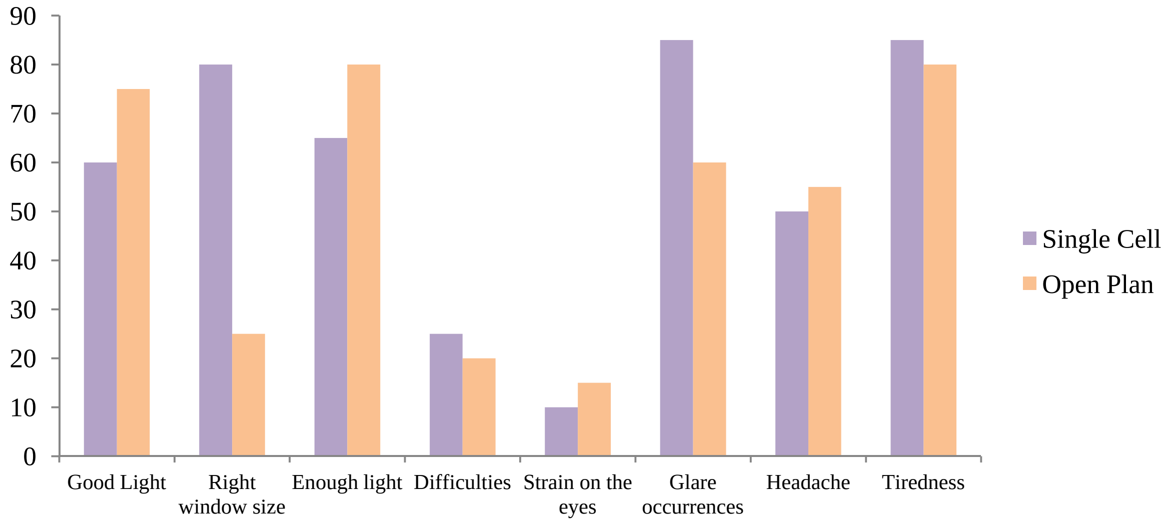

Figure 1 Main questionnaire results

The survey demonstrated that both offices have plenty of light and the main problem consists in glare occurrences. The large amount of light affects the workers performance and productivity. Workers of both offices complain of often headaches and tiredness. Thus, the study is mostly restricted in providing good shading to avoid the large amount of light and especially glare occurrences.

3.2 BUILDING DESCRIPTION

The research field is restricted in the discussion and analyze of two different typologies of office layouts. The two buildings chosen for discussion are built in different periodical, political and economic times. The first to be analyzed is the buildings of Ministry of Labor, Social Affairs and Equal Opportunities (MLSAEO). This building is positioned in the Kavaja Street and has an orientation North-South. It is composed of 5 storey above ground. Offices are arranged along the lateral sides with a corridor in the middle.

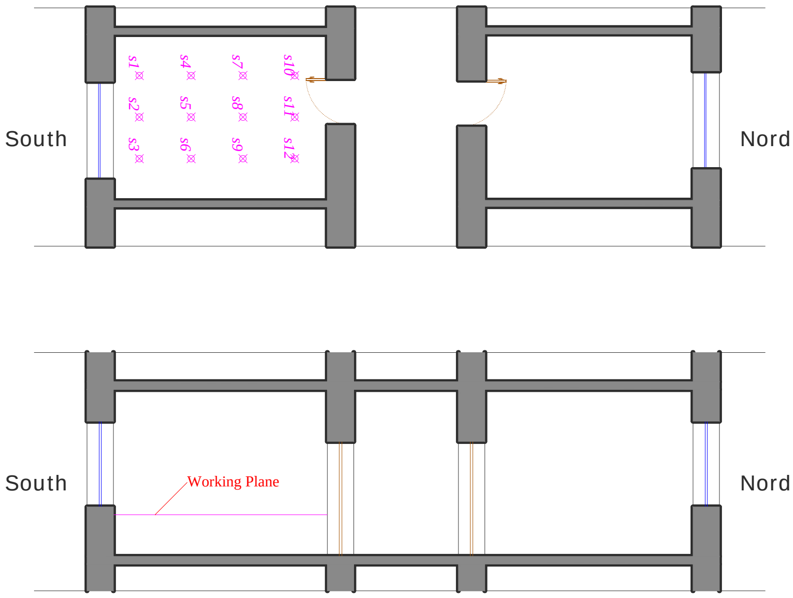

Figure 2 Floor plan and section of single cell office

On the other hand, the second building analyzed is the ABA commercial center designed by Bolles and Willson. It was first build in 2009. The building is composed of several functions. The main function is the commercial one and comprises 12 storeys with offices. In this case, the plan is arranged in a different way from the first case. In the center, the main services like elevators and stairs are positioned. Around the core of the building, four main sectionsare distributed, each one composed of open plan office layout.

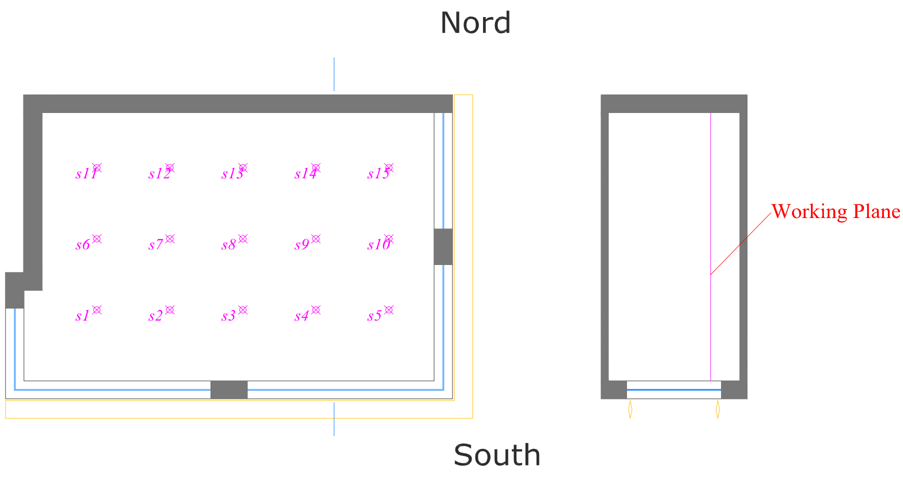

Figure 3 Floor plan and section of open plan office

As can be understood from the plan, offices in the ABA Center have a higher occupancy number and the plan is arranged in bases of open plan offices only.

3.3 SOFTWARE DESCRIPTION

Daylighting describes the act of lighting the interior of a building with daylight. (Reinhart 2010). Daylighting must be introduced in the project in order to provide the building with all the benefits of daylight. However, the designer has to define the daylight performance of the building and to estimate the physical amount of daylight needed in the building. In order to do so, the daylighting project should be assisted by daylight simulation programs.

A daylight simulation is a computer-based calculation which aims to predict the amount of daylight available in a building either under selected sky conditions (static simulation) or during the course of the whole year (dynamic simulation). Daylight simulations calculate physical quantities such as illuminances or luminances due to daylight at selected locations in a building (Reinhart 2010). Thus, simulation programs work on some inputs in order to provide the desired analysis.

The program chosen to perform the daylight simulation is Daysim software. The possibilities and strengths of Daysim are that it links a detailed simulation of light distribution performed in Radiance with a yearly calculation of interior daylight levels (Bülow-Hübe 2008). The process of simulation through Daysim is based on two main parts. The first part, which is the time-consuming one, is to establish a set of daylight coefficients for the selected measurement points. The second part of the process stands in calculating the annual illuminance profile. The calculation is based on a special climate file, starting typically with a standard climate file with one-hour time steps, which is synthetically broken down to shorter time steps, e.g. 5-minute steps (Bülow-Hübe 2008).

Daysim, apart from the climatic files and sensor files, needs also some other inputs in order to provide a real-scale scene. In the input data set, occupancy and luminaires (electrical lighting) are included. Even though most part of office work is done during daytime, sometimes electrical light is needed to supplement daylight (case of overcast). Daysim, which uses Radiance as the simulation engine, is currently the only program that features detailed user behavior algorithms to predict electric lighting energy savings from automated lighting controls and shading devices (Reinhart, Tutorial on the Use of Daysim Simulations for Sustainable Design 2010).

On these briefly mentioned steps the simulation of the two types of buildings is done. Thus, the results provided from the simulations can be analyzed and compared. Numerical results are also compared to the standard requirements for lighting, thus, providing some solutions when needed.

4 CASE STUDIES

4.1 SIMULATION PROCESS

The very first step, after saving the file, is to load an annual climate file. Since the annual climate file for Albania does not exist in the database of EnergyPlus Energy Simulation Software (http://apps1.eere.energy.gov 2011) the simulation is conducted using the climate file for the city of Bari, Italy (Tirana and Bari have almost the same annual climate). After loading the climate file, the building model is loaded and the sensor point file.

For an analysis of the daylight availability in the offices and on the aisle, it makes sense to chose a series of sensors located on a grid (x=1-2 m), (y= 1-2 m) at a height of 85cm (z-0.85), facing upwards (orientation 0 0 1) (Reinhart, 2010). In this case, the most crucial points in each room are established and their coordinates are calculated.

The analysis is performed for the points indicated as sensors and they create the working plane. For all these points the annual illuminance profile is calculated.

4.1.1 SIMULATION ASSUMPTIONS

The investigated building is located in Bari-Palese (41.13 N/ 16.78 W). The zone is occupied Monday through Friday from 8:00 to 17:00. The occupant leaves the office three times during the day (30 minutes in the morning, 1 hour at midday, and 30 minutes in the afternoon). The total annual hours of occupancy at the work place are 1805.9. The electric lighting is activated 1850.2 hours per year. The occupant performs a task that requires a minimum illuminance level of 500 lux.

The optical properties of each element are reported in the below table.

Building element	Material description
Ceiling	66.3% diffuse reflection

Floor	69% diffuse reflection
Wall	75% diffuse reflection
Glass	90% diffuse reflection
Blinds	No blinds

Table 1 Optical properties of building elements

In order to simplify the simulation process and to save time, default Daysim-Radiance parameters are used, and they are listed in Table 2.

Ambient bounces	**Ambient divisions**	**Ambient accuracy**	**Ambient resolution**	**Direct threshold**	**Direct Sampling**
2	512	0.2	128	0	0.2

Table 2 Simulation parameters

At the end of the simulation run an illuminance file gives the result and all values for each sensor. According to these values reached by the simulation a judgment can be done about the daylighting of the offices. In order to simplify the analysis four characteristic days are discussed.

4.2 SIMULATION RESULTS

The same office (single cell and open plan office) has been analyzed for three different scenarios. The first scenario analyzes the existing condition for each type of the office. The two other scenarios consist in the solutions given for optimazing daylighting.

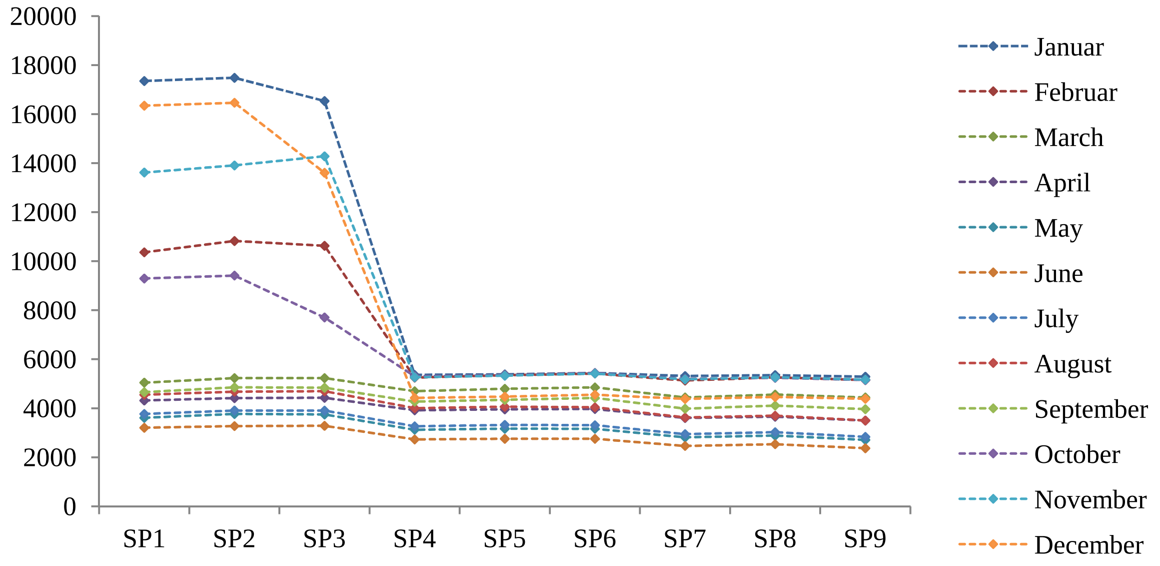

Figure 4 Illuminace values for the single cell office

Figure 3 displays the illuminance values during the year for the single cell office. Through these figures the tendencies of illuminance are given. During summer period, when the sun altitude has higher values, the first row of sensors has higher illuminance values. This result confirms the presence of direct sunlight in the office environment.

Among the results of the simulation are daylight factor (DF) and the useful daylight index (UDI). The daylight factor is defined as the ratio of the internal illuminance at a point in a building to the unshaded, external horizontal illuminance under a CIE overcast sky (Moon and Spencer 1942). However, the daylight factor was never meant to be a measure of good daylighting design but a minimum legal lighting requirement (Reinhart, Mardaljevic and Rogers 2006). Thus the daylight factor is taken for analysis. According to the report given by Daysim, 100% of all illuminance sensors have a daylight factor of 2% or higher. The daylight autonomies for all core workplane sensors lie between 88% and 94%. The Useful Daylight Indices for the Lighting Zone are UDI<100=3%, UDI100-2000=23%, UDI>2000=74% .

x	y	z	**DF(%)**	**UDI<100(%)**	**UDI 100-2000(%)**	**UDI>2000(%)**
1.000	1.000	4.050	6.4	2	29	69
2.000	1.000	4.050	7.7	1	26	73
3.000	1.000	4.050	6.2	2	33	66
1.000	2.000	4.050	4.2	2	42	55
2.000	2.000	4.050	4.5	2	40	57
3.000	2.000	4.050	4.2	2	41	57
1.000	3.000	4.050	3.4	3	51	46
2.000	3.000	4.050	3.4	3	51	47
3.000	3.000	4.050	3.4	3	50	47
1.000	4.000	4.050	3.2	3	55	43
2.000	4.000	4.050	3.3	3	53	44
3.000	4.000	4.050	3.2	3	55	42

Table 3 Results of simulation of existing office

Figure 4 displays the illuminance values during the year, results of the Aba office simulation process. It is obvious that sensors having the highest values are the one being exposed to both south and east. The lowest values are seen in the sensors near the walls. However, results from the simulation show that the office suffers of high illuminance values.

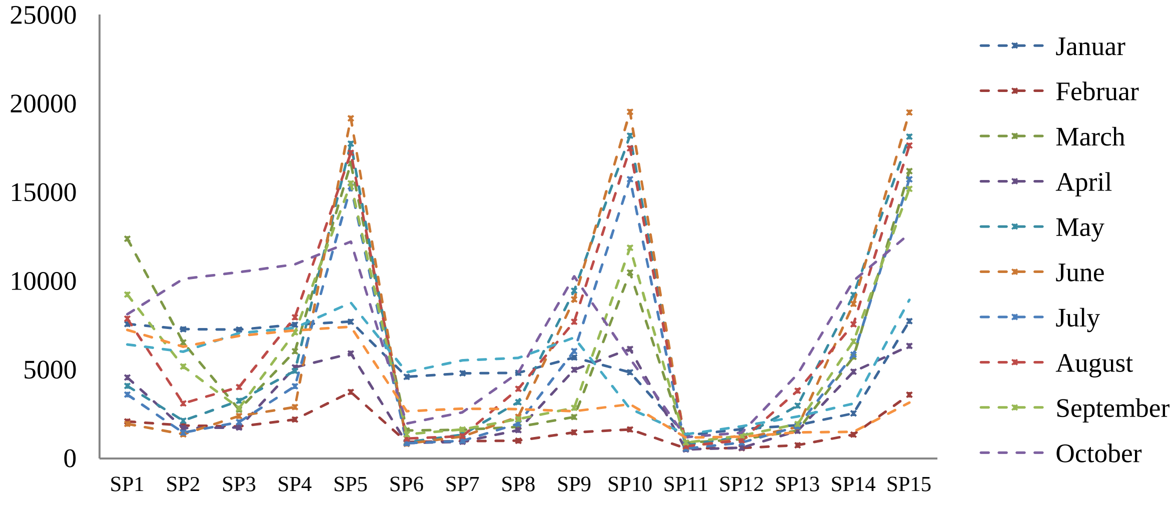

Table 4 Illuminance values for open plan office

Other results of the simulation show that 33% of all illuminance sensors have a daylight factor of 2% or higher. The daylight autonomies for all core workplane sensors lie between 12% and 83% . The Useful Daylight Indices for the Lighting Zone are UDI<100=21%, UDI100-2000=43%, UDI>2000=36% . These results are displayed below in table 5.

x	**y**	**z**	**DF [%]**	**UDI$_{<100}$ [%]**	**UDI$_{100-2000}$ [%]**	**UDI$_{>2000}$ [%]**
3.000	**2.500**	**28.510**	2.1	7	75	18
5.000	**2.500**	**28.510**	1.7	7	83	10
7.000	**2.500**	**28.510**	1.6	8	85	7
9.000	**2.500**	**28.510**	2.2	7	81	12
11.000	**2.500**	**28.510**	3.4	6	65	29
3.000	**4.500**	**28.510**	0.8	12	87	1
5.000	**4.500**	**28.510**	0.8	11	88	1
7.000	**4.500**	**28.510**	1.0	10	88	1

9.000	**4.500**	**28.510**	1.5	8	89	3
11.000	**4.500**	**28.510**	3.4	6	82	11
3.000	**6.500**	**28.510**	0.5	21	79	0
5.000	**6.500**	**28.510**	0.5	17	83	0
7.000	**6.500**	**28.510**	0.8	12	87	0
9.000	**6.500**	**28.510**	1.2	10	89	1
11.000	**6.500**	**28.510**	3.5	6	78	16

Table 5 Results of simulation of open plan office

4.2.1 RESULTS FOR SUGGESTED SCENARIOS

For the single cell office the suggested solutions consist in lowering illuminance values and espacially lowering the direct sunlight and increasing of diffuese reflected sunlight. Thus both solution suggested consist in two types of light shelf shadings (short and long).

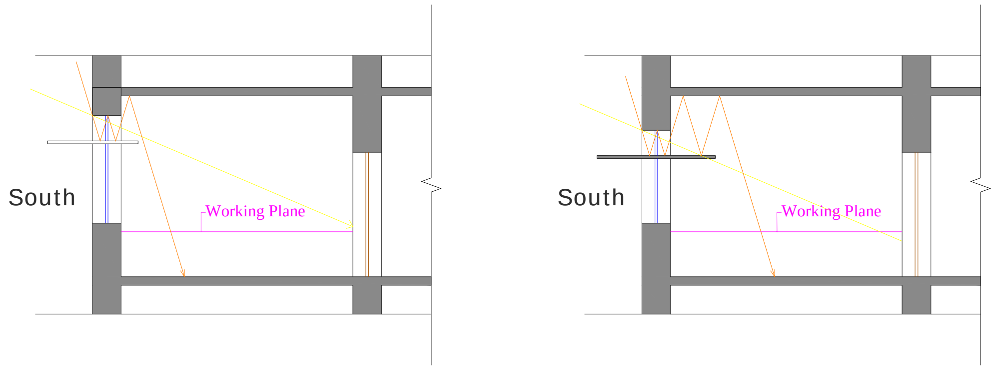

Figure 5 Suggested solution scenarios for single cell office

For the first solution suggested the simulation process gave results as mentioned below:

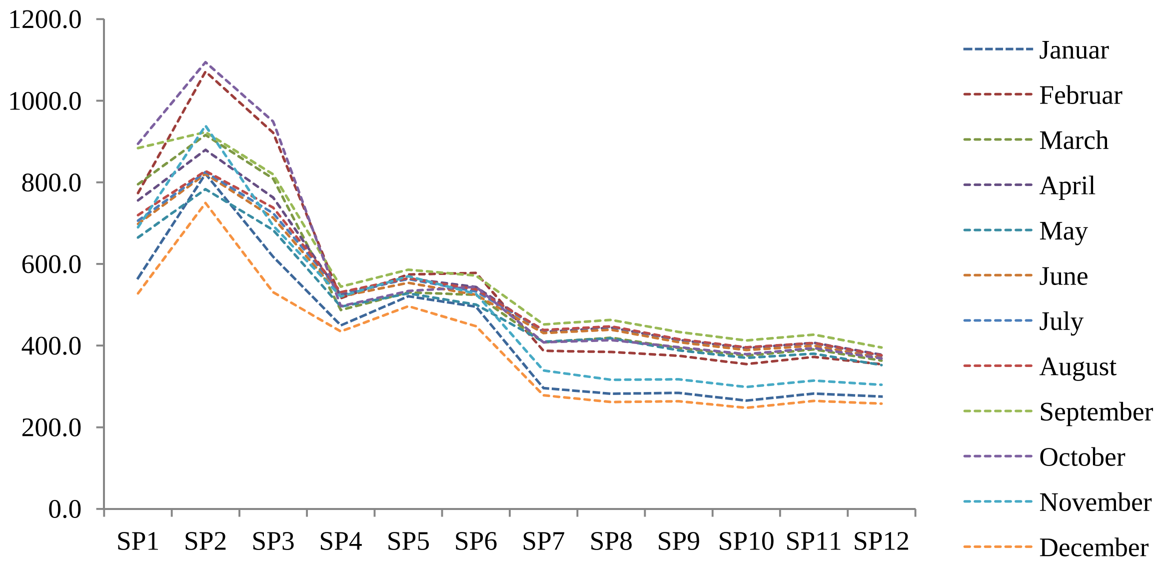

Figure 6 Annual Illuminance values for the first solution suggested for the single cell office

Results of the simulation for the first solution scenario proposed for the single cell office show that illuminance values are generally lowered and for this scenario more uniform light is obtained. However, sensor points near the window have illuminance values above 500lux but the last row of points has illuminance values under minimum accepted illuminance level of 500lux.

x	y	z	DF [%]	$UDI_{<100}$ [%]	$UDI_{100-2000}$ [%]	$UDI_{>2000}$ [%]
1.000	**1.000**	**4.050**	3.3	3	56	41

2.000	**1.000**	**4.050**	4.1	2	42	56
3.000	**1.000**	**4.050**	3.2	3	54	43
1.000	**2.000**	**4.050**	2.2	4	84	13
2.000	**2.000**	**4.050**	2.4	4	79	18
3.000	**2.000**	**4.050**	2.3	4	80	16
1.000	**3.000**	**4.050**	1.8	4	90	6
2.000	**3.000**	**4.050**	1.9	4	90	6
3.000	**3.000**	**4.050**	1.7	4	91	5
1.000	**4.000**	**4.050**	1.7	4	92	4
2.000	**4.000**	**4.050**	1.7	4	91	5
3.000	**4.000**	**4.050**	1.6	5	92	4

Figure 7 Results of the first proposed solution scenario for single cell office

According to the results of the simulation analyzis for the first proposed solution for the single cell office, 54% of all illuminance sensors have a daylight factor of 2% or higher. These values are positioned mainly in the rows of sensors near the window. The daylight autonomies for all core workplane sensors lie between 74% and 89% . The Useful Daylight Indices for the Lighting Zone are UDI<100=5%, UDI100-2000=40%, UDI>2000=55%. More detailed the results are shown in Figure.6.
As observed from the results the desired results are not achieved yet. For this reason the second solution scenario is proposed. It consists in extending the inner light shelf in order to enhance the reflected uniform light in the office.

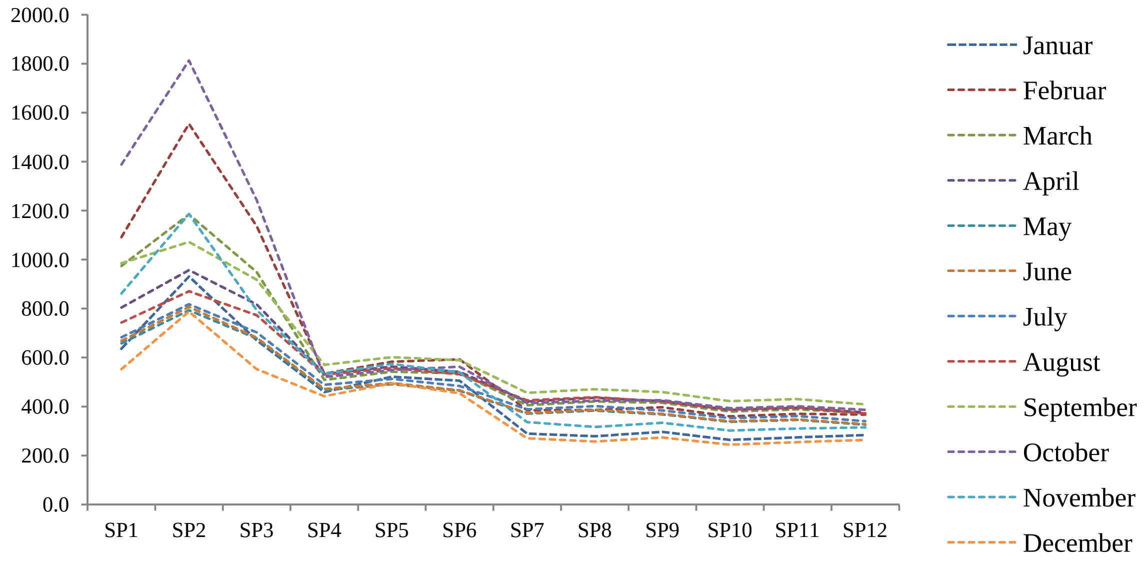

Figure 8 Annual Illuminance values for the second solution scenario proposed for single cell office

Figure 7 displays the annual illuminance values for the second solution scenario proposed for the single cell office. It is obvious that the illuminance values are more uniform for the most part of the sensor points. Only the first row of sensors have high illuminance values, due to the direct sunlight that penetrates the office, especially during winter period.
Below, in Table 6, are shown other results obtained from the simulation analyzis.

x	y	z	DF [%]	$UDI_{<100}$ [%]	$UDI_{100-2000}$ [%]	$UDI_{>2000}$ [%]
1.000	**1.000**	**4.050**	3.5	3	57	41
2.000	**1.000**	**4.050**	4.5	2	41	57
3.000	**1.000**	**4.050**	3.4	3	55	42
1.000	**2.000**	**4.050**	2.2	4	80	16
2.000	**2.000**	**4.050**	2.3	4	76	20

3.000	**2.000**	**4.050**	2.1	4	77	19
1.000	**3.000**	**4.050**	1.6	5	89	7
2.000	**3.000**	**4.050**	1.7	5	88	7
3.000	**3.000**	**4.050**	1.7	5	88	7
1.000	**4.000**	**4.050**	1.5	5	90	5
2.000	**4.000**	**4.050**	1.5	5	90	6
3.000	**4.000**	**4.050**	1.5	5	90	5

Table 6 Results of second solution scenario for single cell office

The same methodology was conducted for the open plan office analyzis. The first suggested solution scenario for the open plan office consist in adding shadings same as the existing ones but at a shorter distance.

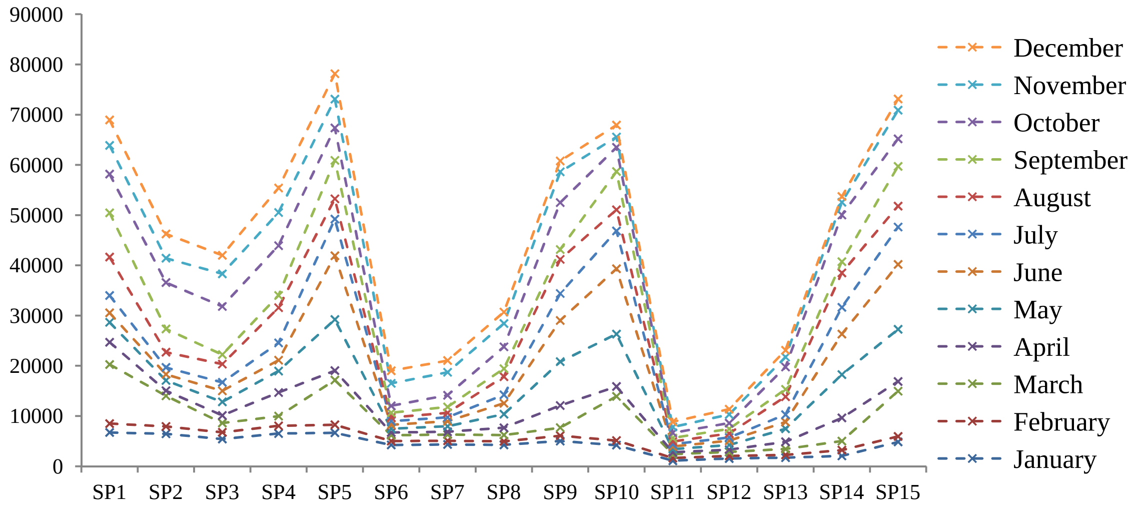

Figure 9 Illuminance values during the year for the first solution scenario

From the results of the simulation for the first suggested solution none of all illuminance sensors have a daylight factor of 2% or higher. The daylight autonomies for all core workplane sensors lie between 7% and 75% . The Useful Daylight Indices for the Lighting Zone are UDI<100=20%, UDI100-2000=67%, UDI>2000=14% .

x	y	z	DF [%]	UDI$_{<100}$ [%]	UDI$_{100-2000}$ [%]	UDI$_{>2000}$ [%]
3.000	**2.500**	**28.510**	1.8	7	82	11
5.000	**2.500**	**28.510**	1.3	8	87	4
7.000	**2.500**	**28.510**	1.2	9	88	3
9.000	**2.500**	**28.510**	1.6	8	88	4
11.000	**2.500**	**28.510**	1.9	7	86	7
3.000	**4.500**	**28.510**	0.7	14	86	0
5.000	**4.500**	**28.510**	0.7	12	88	0
7.000	**4.500**	**28.510**	0.8	12	88	1
9.000	**4.500**	**28.510**	1.0	11	88	1
11.000	**4.500**	**28.510**	1.7	8	90	2
3.000	**6.500**	**28.510**	0.5	19	81	0
5.000	**6.500**	**28.510**	0.5	17	83	0
7.000	**6.500**	**28.510**	0.6	16	84	0
9.000	**6.500**	**28.510**	1.0	11	88	1
11.000	**6.500**	**28.510**	1.7	8	89	3

On the other hand the second suggested solution scenario consist in implementing venetian blinds within the double glass of the windows.

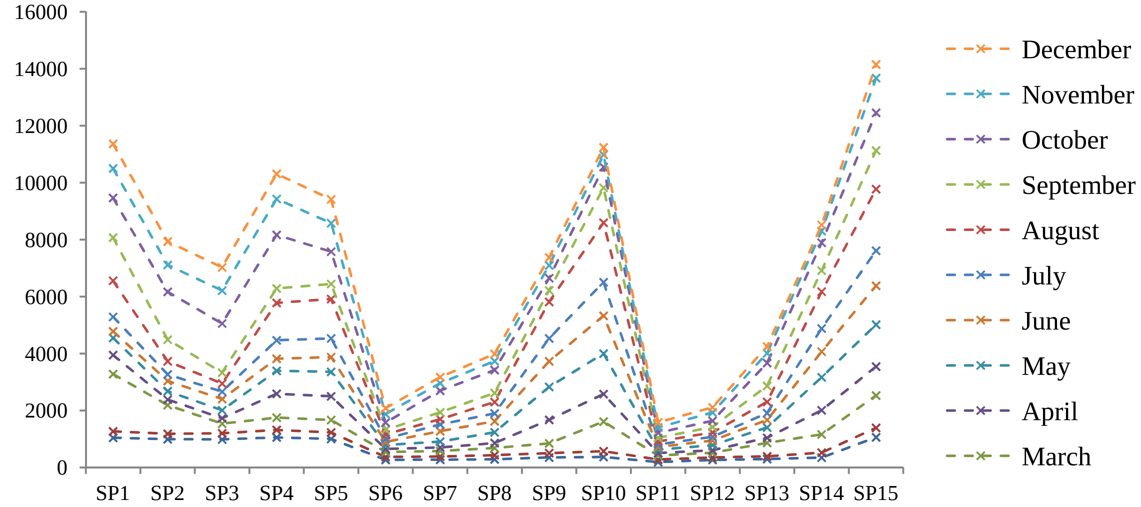

Figure 10 Illuminance values during the year for the second suggested scenario

As shown in the results none of all illuminance sensors have a daylight factor of 2% or higher. The daylight autonomies for all core work plane sensors lie between 0% and 5% . The Useful Daylight Indices for the Lighting Zone are UDI<100=96%, UDI100-2000=4%, UDI>2000=0%.

x	y	z	DF [%]	$UDI_{<100}$ [%]	$UDI_{100-2000}$ [%]	$UDI_{>2000}$ [%]
3.000	**2.500**	**28.510**	0.2	43	57	0
5.000	**2.500**	**28.510**	0.1	53	47	0
7.000	**2.500**	**28.510**	0.2	50	50	0
9.000	**2.500**	**28.510**	0.2	43	57	0
11.000	**2.500**	**28.510**	0.2	42	58	0
3.000	**4.500**	**28.510**	0.1	88	12	0
5.000	**4.500**	**28.510**	0.1	81	19	0
7.000	**4.500**	**28.510**	0.1	69	31	0
9.000	**4.500**	**28.510**	0.2	62	38	0
11.000	**4.500**	**28.510**	0.4	43	57	0
3.000	**6.500**	**28.510**	0.1	96	4	0
5.000	**6.500**	**28.510**	0.1	93	7	0
7.000	**6.500**	**28.510**	0.1	88	12	0
9.000	**6.500**	**28.510**	0.2	65	35	0
11.000	**6.500**	**28.510**	0.4	43	57	0

Table 7 Results of the second suggested scenario for open plan office

4.2.2 ENERGY CONSUMPTION RESULTS

Each scenario (both existing conditions and proposed ones) is analyzed also for the energy consumption. The conditions for analyzing the energy consumption are:

- The occupant performs a task that requires a minimum illuminance level of 500 lux.
- The zone is continuously occupied Monday through Friday from 8:00 to 16:30.
- The total annual hours of occupancy at the work place are 2088.4.
- The office has no dynamic shading device system installed.

In order to facilitate the analyzis the results are displayed in Table 8.

Scenario	Annual electric lighting energy	Total annual lighting energy	Electric lighting activated h/year
Single Cell Existing	10.9 kWh/m²	145.2 kWh	698.3
Single Cell First Solution	15.1 kWh/ m²	200.9 kWh	926.8

Single Cell Second Solution	15.7 kWh/ m²	209.1 kWh	892.4
Open Plan Existing	6.9 kWh/ m²	637.1 kWh	1004.1
Open Plan First Solution	6.9 kWh/ m²	634.7 kWh	972.4
Open Plan Second Solution	14.7 kWh/ m²	1348.0 kWh	1996.3

Table 8 Electricity consumption results

Simulation results show that proposed solution scenarios fulfill the first aim of the study: lowering the illuminance values and as a results avoiding glare occurrences. In the first case study, by analyzing the results we can see that by lowering the overall illuminance values, the values of the last row of sensors is lowered under the limit level of 500 lux. This is the reason why the electricity consumption in this case is higher. Even though both of proposed solution scenarios consisted in enhancing the diffused reflected light in the office, the last rows of sensors have difficulties in achieving the limit level of illuminances.

On the other hand, for the second typology of office, the first solution proposed shows better results in lowering the enegy consumption but it does not achieve best results in lowering the illuminance values and lowering glare occurrencies. However, the second solution proposed succeeds in lowering the illuminance values and achieving more uniform light but fails to lower the energy consumption.

5 CONCLUSION

Optimizing daylight in office buildings is the final result of the study carried on. The study was focused in three main steps. Firstly existing issues in lighting and daylighting are made present. Secondly, one of the key issues of the study was the users preference and need for comfortable lighting. The study revealed that majority of workers complain of glare occurrences and high amount of light. The third step consisted in providing different solution models, comparing them and finally selecting the best practice.

This way of study arrangement was concluded in a series of valuable conclusions which are grouped in three main categories.

5.1 DAYLIGHTING AND ELECTRICITY CONSUMPTION

After the deep analysis of the two prototype offices three main categories of conclusions are carried out. The first conclusions are related to the energy savings. Since offices facing south and those of large amount of glazing area suffer the large amount of light, there is no need of artificial light. The daylight availabel to these offices should be used appropriately in order to minimize the usage of electricity. In other words, design of offices and especially optimization of offices should be focused in applying and considering daylight saving time.

Survey and simulation results show that in an office daylighting controls should be provided (daylight dimming). By using available sunlight, energy consumption of the electric lighting is reduced. On the other hand, daylighting controls are used also as optimum solution in avoiding and reducing glare.

5.2 SHADING DESIGN

Analysis, survey and simulations, show that the main concerning problem affecting different prototypes of offices in Tirana is glare. Offices in Tirana suffer glare due to absence of shadings. Most of the offices use direct sunlight (producing glare) instead of a diffuse light. Presence of direct sunlight not only is the main factor causing glare occurrences but it also creates a misbalance of light. Posts near windows suffer high amount of light and the others away from windows suffer not enough amount of light.

The study recommends to perform in-depth analysis of the building geometry and to provide shadings that reduce direct sunlight and enhance diffuse lighting.

5.3 FUTURE RECOMMENDATIONS

The study showed that every type of office has its characteristic daylight issues. A large amount of factors should be taken into consideration while designing with daylight. Design with daylight can result in problematic design when design in performed as standard one. Each office building has its own special characteristics that affect daylight.

Thus, the study recommend that daylight simulation should be performed during design of new offices or reconstruction of existing ones in order to provide the best scenario of daylighting needed to enhance worker performance. Using simulation tools makes possible the analysis of each factor affecting daylight. During this process characteristics are analyzed not only generals. However, in order to implement them successfully, future studies on simulation tools should be carried out.

Future possible studies would comprise comparison of different simulation tools performance and results; analyzing of other building typologies and even urban scale simulations.However, the current study showed the basic difficulties in applying simulation tools. One of the main inputs, weather data file, was selected from Bari, Italy since there is no such file for Tirana, Albania. Thus, the recommendations for the near future are concerned with applying studies and researches in order to ensure right inputs for further simulations.

The usage of simulation programs promises high achievements and results for architectural design. All input assumptions have little percentage error and are closer to reality.

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