Impact of Windows on Interior Environment in Office Buildings Located in Hot and Arid Region: Thermal and Visual Performance

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Abstract

Enjoying the heat and natural light in any indoor space are considered the most important functions of the window. In order for a window to contribute effectively to the increase of thermal and visual efficiency in buildings and especially to those located in areas with hot and arid climates, the selection of the best parameters must be made as early as design in the building process, but unfortunately most Algerian architects consider the window as an aesthetic aspect for the facades without paying attention to their yields.

In this respect, this article presents an experimental study carried out to clarify the impact of different configurations of windows on visual and thermal efficiency using simulation software on models of real offices located in the city of Biskra. , oriented south and released from a typological study. The simulation process was carried out during the 3 months (March, June, December), taking into account the climatic data of the city of Biskra. The experimental results obtained confirm the efficiency of the window, as an element makes it possible to contribute to the achievement of comfort conditions within a space.

Keyword: Window; thermal efficiency; visual efficiency; office buildings; hot and arid zone.

1. Introduction

In a whole building, the key element that ensures the relationship between indoor space and the outdoor environment and guarantees an ambitious indoor climate is "the window". (John, A., Ballinger., Peter, R., Lyons, 1996).

Given its importance in a whole exchange outside - inside, we must first know its duality of advantage and inconvenience. Because according to (Gay, 2001), the window is a complex element for more than one reason. It is required to perform various important functions: source of natural light, heat, natural ventilation and vision to the outside world, and each of these functions is related to an undesirable effect: source of glare, overheating, noise and reduction of visual privacy (Ilknur, T., Mehmet .T, 2007). So the best window was - in the absolute - the one that would answer all the functions in a well studied and controlled way.

In a workspace, natural light and heat are the most requested window functions (J., H., Heerwagen, and Gordon., H., Orians, 1986) as they can reduce energy consumption due to the use of artificial lighting and heating or cooling equipment and reduce stress and fatigue and give the space user a vision on external conditions (Hellinga H, Hordijk T, 2014).

For this, a window that guarantees access for natural light and ensures a balance between the gains and needs of heat quantitatively and qualitatively adequate for a workspace must be well studied in terms of all its parameters: configuration, sizing, position, type of glazing, sunscreen ... etc, in order to achieve comfort conditions and visual and thermal interior quality bearable for workers. (G. F. Menzies, J. R. Wherrett, 2005)

2. Purpose of work

The overall objective of this article is to study the effect of the window on the visual environment and the amount of solar energy reduced within a space.

But specifically, the goal is to know the optimal parameters related to the window compared to the WWR and sun protection in order to achieve an ideal thermal and visual quality for the occupants of the office spaces located in a zone hot and arid in terms of amount of natural light from simulated illumination levels and reduced solar energy by evaluating the shading coefficient required for each orientation.

3. Methodology

The main objective of this study is to have a vision on the effect of certain parameters related to the window within the interior space from the selected models. These models were simulated under inputs of the city's climate data of Biskra, to define their visual and thermal performance in this hot and arid region. To reach this goal:

• Three (03) test models were chosen with different geometric characteristics from an analytical study on some office buildings in the city of Biskra.

• These three (03) models were used to test the effect of different opening ratios with un-studied solar protection on the amount of light offered in a horizontal work surface and on reduced solar energy.

• The same three (03) models will be studied after a correction corresponding to each model.

3.1. Main steps of the experimental work:

The main stages of the research are described as follows:

a. Choice of buildings: a typological study has been drawn up, grouping different buildings of the offices located in the city Biskra.

b. Simulation tool:

- Simulations of sunny and shaded surfaces were performed using the Ecotect V5.5 software.
- The simulations for the study of the levels of illumination were carried out using the software Radiance 2.0 BETA.

c. Simulation period:

- The period of the experiment is fixed at Solstice Days and Spring Equinox (December 21st, June 21st and March 21st).
- The hours of thermal simulation: every hour of the day (from sunrise to sunset).
- The hours of the illumination simulation: at 8h, at 12h and at 16h.

d. Reference values:

- After simulating the effect of shading for all the models, a summary table allowing the collection of these data and preparing their synthesis has been elaborated.

• The calculation of the optimal Shading Coefficient (%) = 100- H / G (or H / G calculated in %)

- The application of the method of (Novell, 1983) by (T.Mezerdi, 2011) using the temperatures maximum, minimum and average levels in the city of Biskra, resulted in the results following:

- The need for shading extends to more than 51% of the year
- The shading requirement for the month of December is 0.00%
- The shading requirement for the month of March is 43.33%
- The shading requirement for the month of June is 100%

- For the interpretation of the results in terms of illuminance, reference values developed by Nbil, A and Mardaljavie, J (Nabil, A., Mardaljevic, J, 2005) in their study "100 lux as a value of minimum illuminance and 2000 lux as maximum value for a space of job ".

3.2. The typological study:

In this category of buildings (office space), the selection of projects is based on two essential variables:

- ✓ The different ratios of the openings used in the facade for the south orientation.
- ✓ The correct use of sun protection elements, taking into consideration all their parameters.

The selected buildings are as follows:

B1: the direction of energy and mines. (Fig.1)

B2: the land agency. (Fig.2)

B3: Direction of the technical control of the building (CTC). (Fig.3)

B4: Public Works Direction (DTP). (Fig.4)

B5: The old seat of the central administration of the University of Biskra (Fig.5)

Figure 1. Direction of Energy and Mines. (Author)

Figure 2. Agency of land. (Author)

Figure 3. Direction of the technical control of the buildings. (Author)

Figure 4. Public work direction. (Author)

Figure 5. The old seat of the central administration of the University of Biskra. (Author)

The models obtained:

The models chosen are real office spaces located in the examples analyzed previously. This so that we can make a correction in these examples and make a comparison between the models before and after the modification. (Table.1)

Table 1. Choice of models. (Author)

	Office size	Window size	Window wall ratio	The use of solar shading devices	orientation
01	5.10x4.20=21.42m²	1.60x1.60=2.56m²	14.34%	Not dimensioned	South
02	6.00x4.80=28.8m²	4.50x3.20=14.40m²	60%	No use	South West
03	4.00x3.10=12.4m²	1.20x1.00=1.20m²	9.40%	Not adapted	South

Applicable corrections:

In order to achieve the objective of our study a correction of the chosen models was done with an optimal solution concerning the types of solar protections used for each model as it is indicated in the table below (table.2):

Table 2. The corrections of the models. (Author)

models	Before correction	Correction
Model 01	-The window in this model is equipped with a combined solar shading canopy and between unsized flank (depth = 0.75m).(table.3) - this type of sun breezes has a very good efficiency in South orientation	- resizing of the awning depth: * the required value of the occultation height in the south orientation = 43 ° So: tag20 ° x1.60 = 1.71m deep.(table.3)
Model 02	- Southwest facing window without any solar shading device.(table.4)	- The addition of a combined light shelf (indoor and outdoor) with a semi-reflective surface.(table.4)
Model 03	- South-facing window with vertical sunshades not adapted to this orientation.(table.5)	- The addition of light guiding shades.(table.5)

Table 3. Model 01 for simulation. (Author)

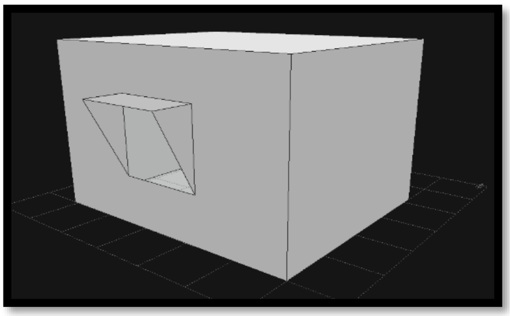
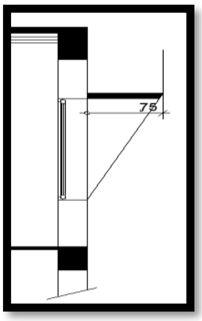
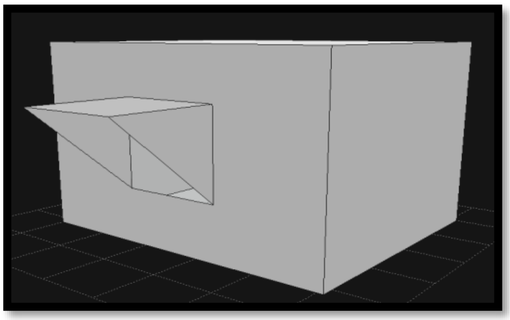
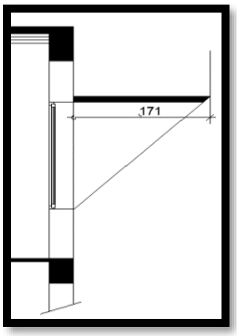
Model 01		
	Model configuration	Window section
before correction		
After correction		

Table 4. Model 02 for simulation. (Author)

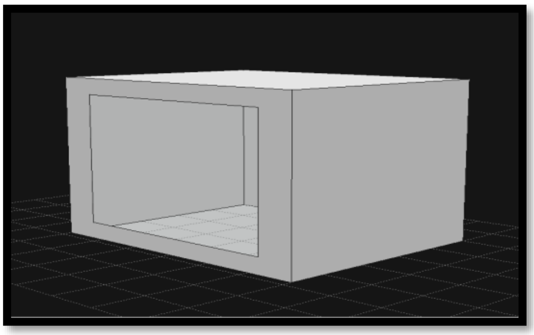
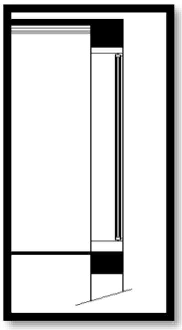
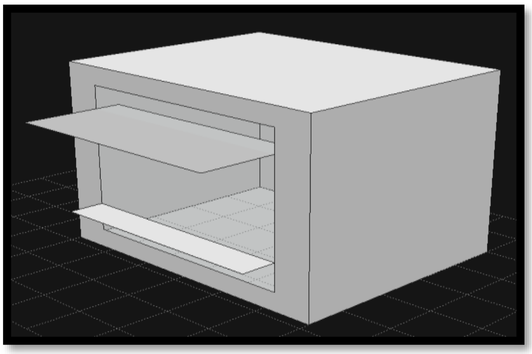
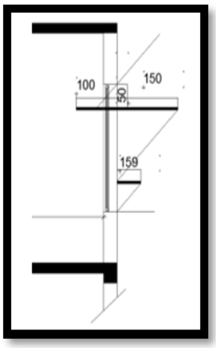
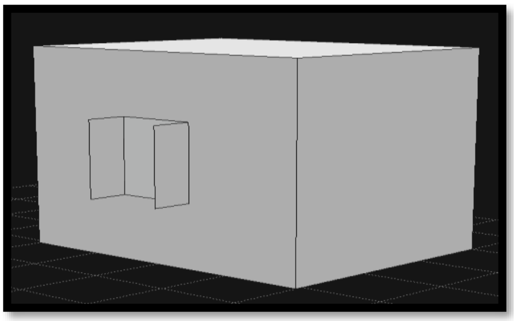
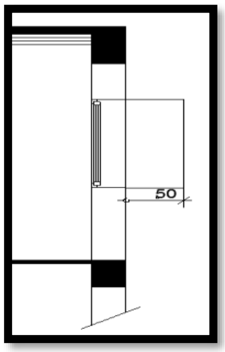
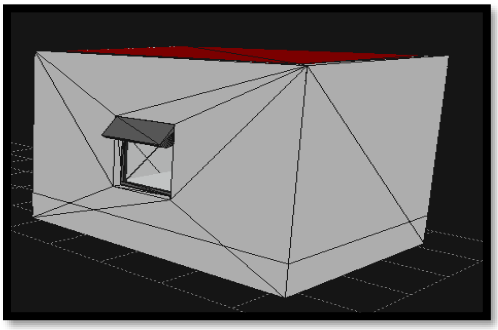
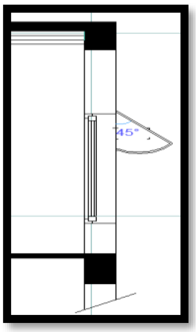
Model 02		
	Model configuration	Window section
Before correction		
After correction		

Table 5. Model 03 for simulation. (Author)

Model 03		
	Model configuration	Window section
Before correction		
After correction		

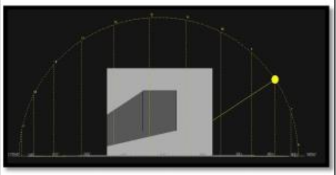
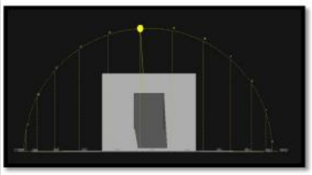
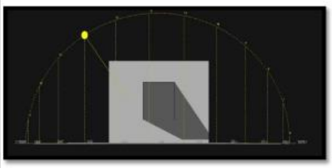
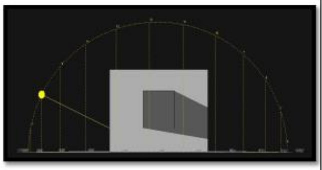
4. Calculation and simulation:

4.1. Thermal performance study:

To clarify the steps of calculation and simulation, we will only present one model (model 01 before the correction) for a single month (March). And these steps are the same in all models studied (before and after the correction).

A. Simulation of sunny and shaded areas (table.6)

Table 6. Simulation of sunny and shaded surfaces for models 01 before correction (March)

	
8H	**12H**
	
14H	**16H**

B. Calculation of sunny and shaded areas (table.7).

Table 7. Sunny and shaded areas for model 01 before correction (March)

Hours	**Facade Surface (m^2)**	**Sunny Surface (m^2)**	**Shaded Surface(m^2)**
heures	**Surface de la façade (m^2)**	**Surface ensoleillée (m^2)**	**Surface ombragée (m^2)**
7.00h	17.85	13.55	4.30
8.00h	17.85	14.06	3.79
9.00h	17.85	14.79	3.046
10.00h	17.85	15.80	2.05
11.00h	17.85	15.95	1.90
12.00h	17.85	15.74	2.11
13.00h	17.85	15.12	2.73
14.00h	17.85	14.51	3.34
15.00h	17.85	13.69	4.16
16.00h	17.85	12.86	4.99
17.00h	17.85	12.73	5.12
18.00h	17.85	0.00	0.00

C. Calculation of optimal shading coefficient (table.8).

Table 8. Optimal shading coefficient for 01 models before correction (March)

	A (m^2)	**Energie Wh/m^2**	**Surface Ensoleillées (m^2)**	**G**	**H**	
heure	**Surface**	**B**	**C**	**A*B**	**B*C**	**Coefficient D'ombrage optimal**
6-7	17.85	32	13.55	571.20	433.60	
7-8	17.85	126	14.06	2249.10	1771.56	
8-9	17.85	229	14.79	4087.65	3386.91	
9-10	17.85	317	15.80	5658.45	5008.60	
10-11	17.85	380	15.95	6783.00	6061.00	
11-12	17.85	413	15.74	7372.05	6500.62	
12-13	17.85	413	15.12	7372.05	6244.56	**19%**
13-14	17.85	380	14.51	6783.00	5513.80	
14-15	17.85	317	13.69	5658.45	4339.73	
15-16	17.85	229	12.86	4087.65	2944.94	
16-17	17.85	126	12.73	2249.10	1603.98	
17-18	17.85	32	0.00	571.20	0.00	
				Σ (A.B)	Σ (B.C)	
				53442.90	43808.30	H/G=0.81

D. Calculation of the amount of shadow required and obtained for the model before and after the correction for the three months (Table 9).

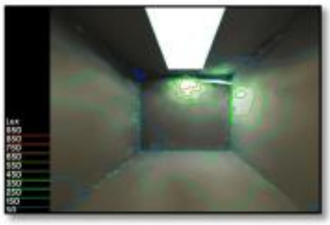
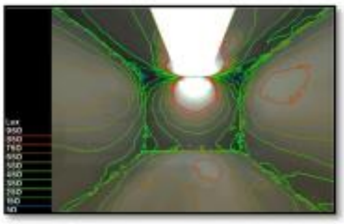
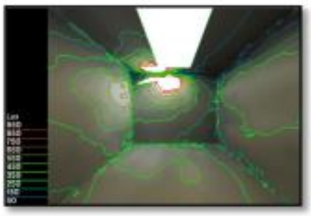
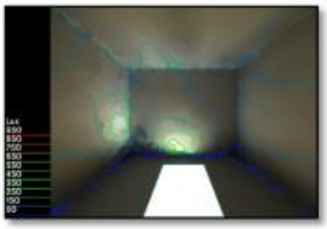
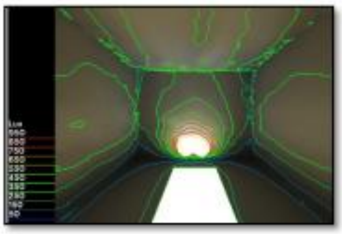
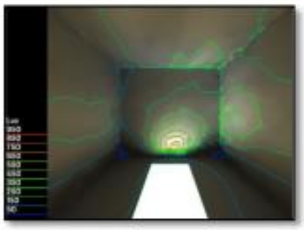
Table.9. Table of required shadow quantities obtained for model 01 before and after correction

Month	Shadow required	Shadow obtained		conformity	
		Before correction	After correction	Before correction	After correction
March	43.33%	19%	34%	No	Yes
June	100%	28%	31%	No	No
December	0.00%	16%	8%	No	Yes

4.2. Lighting performance study: illuminance simulation

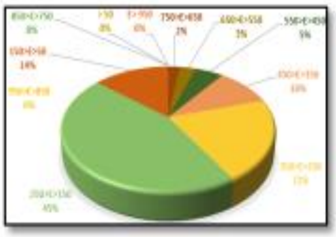
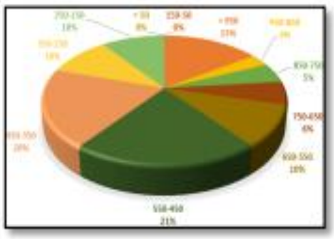
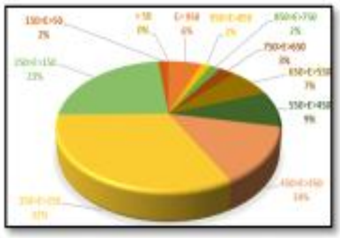
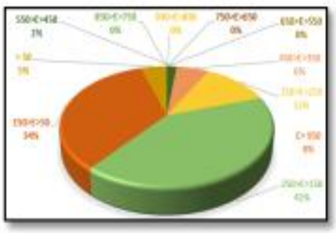
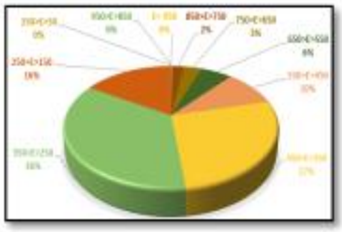
A. Illuminance level simulation at 8.00h, 12.00h and 16.00h (table.10).

Table10. Simulation of illuminance received on the worktop in model 01, 21 March at 8.00h, 12.00h and 16.00h.

	8.00h	12.00h	16.00
avant			
après			

B. Presentation of illuminance zones in percentage at 8.00h, 12.00h and 16.00h (table.11).

Table 11. Percentage illuminance zones in model 01 before and after correction, March 21st at 8.00h, 12.00h and 16.00h

	8.00h	12.00h	16.00
avant			
après			

C. Overall model results before and after the correction for each month (Table 12)

Table 12. Summary table of average illuminance areas in (%) model 01 in March before and after the correction.

Before correction		After correction	
Average illuminance areas in%	Remarks	Average illuminance areas in%	Remarks
5%< 150 lux	Insufficient	15%< 150 lux	Insufficient
150<74%<550	Adequate	150<74%<550	Adequate
550 <14%< 950	Desirable	550 <9%< 950	Desirable
7%> 950 lux	Uncomfortable	2%> 950 lux	Uncomfortable

5. Results and discussion:

5.1. Interpretation of results in terms of thermal performance

Model 01 before and after the correction

Although the shadow quantity values obtained in the 01 model before and after the correction are not all compatible with the values of the amount of shadow required for each month, the results presented in the figure (Fig.6) confirm that the correction made on the dimensions of the solar breeze in model 01 affects the amount of energy radiation received in buildings by reducing the solar gains and by modifying the thermal losses crossing the envelope of which:

- The ensured reduction in the energy transmission of direct solar radiation for the model after the correction is 8% during the cold period (represented by the month of December) while its value before the correction is 16%. This indicates that a quantity of 92% of direct radiation is transmitted, which is favorable for the cold season.

- Also for the summer period (represented by the month of June) the results obtained confirm the contribution of a qualifying optimization of positive in the measurement. Although the values are not confirmed with the necessary shading values, the ensured reduction in energy transmission of direct solar radiation in the model after the correction is 4% more compared to the reduction obtained in the case before the correction. (Table.13).

Reduced amount of energy W/m²

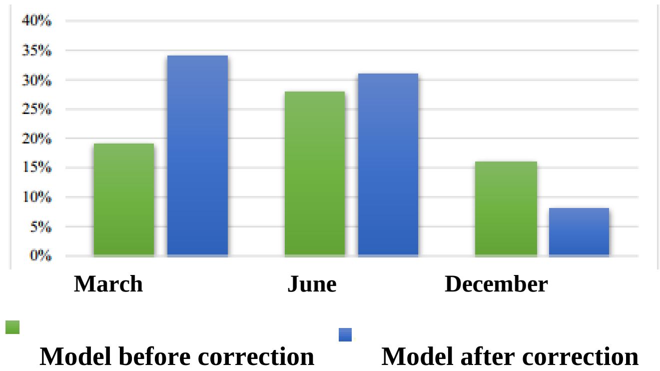


Figure 6. Reduced energy quantities in model 01 before and after the correction. (Author)

Table 13. Table of required shadow quantities obtained for model 01 before and after correction

Month	**Shadow required**	**Shadow obtained**		**conformity**	
		Before correction	After correction	Before correction	After correction
March	43.33%	19%	34%	No	Yes
June	100%	28%	31%	No	Yes
December	0.00%	16%	8%	No	Yes

Model 02 before and after the correction

The results obtained for the light shelf system have favorable optimization values (fig.7), ie for the cold period whose direct radiation reduction is 23%, or for the hot period where the highest value is noted for the reduction of radiation (69%).

- Despite this qualifying positive optimization for this model corrected with the use of the light shelf during the cold season, it seems however that it is not very satisfactory in comparison with the required shade value (0.00%) from the Novell method. (table.14)

Table 14. Table of required shadow quantities obtained for model 02 before and after correction

Month	**Shadow required**	**Shadow obtained**		**conformity**	
		Before correction	After correction	Before correction	After correction
March	43.33%	0%	58%	No	Yes

June	100%	0%	69%	No	Yes
December	0.00%	0%	23%	No	No

Reduced amount of energy W/m²

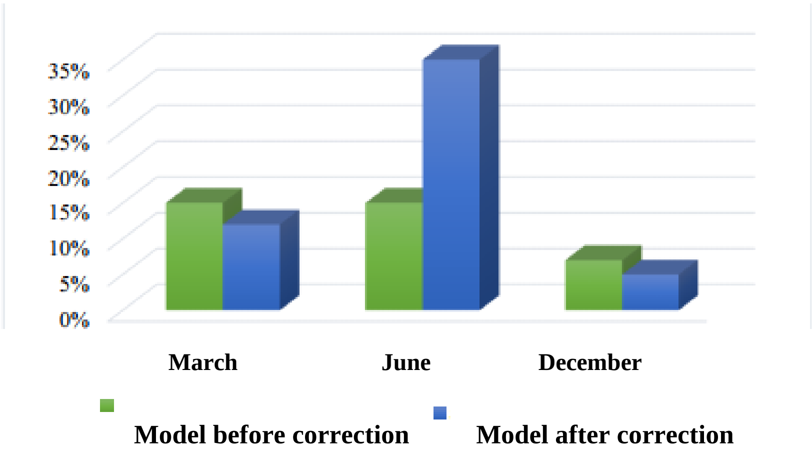


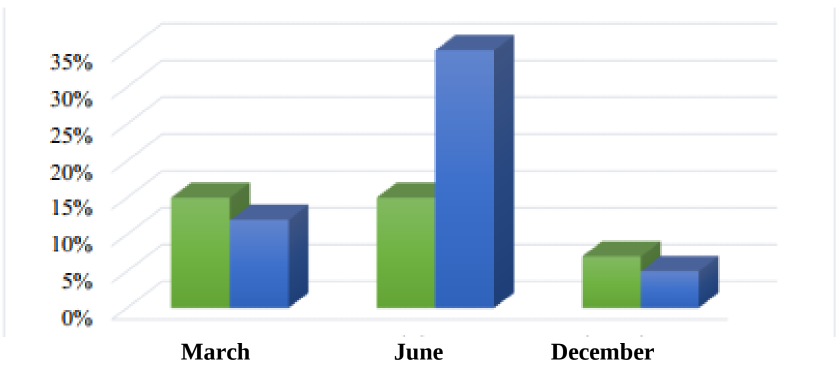
Figure 7. Reduced energy quantities in model 02 before and after the correction. (Author)

Model 03 before and after the correction

If we make a comparison between the model before the correction and the model after the addition of light guiding shade system (fig.8), we notice that this system affect the amount of energy radiation received in buildings by reducing solar gains and modifying thermal losses through the envelope.

- The results obtained have favorable optimization values, either for the cold period of which the reduction in direct radiation is 5%, or for the hot period where the highest value for the reduction of radiation is observed (35%) although it appears that it is not very satisfactory compared to the required shade value from the Novell method. (table.15)

Reduced amount of energy W/m²



Model before correction **Model after correction**

Figure 8. Reduced energy quantities in model 03 before and after the correction. (Author)

Table 15. Table of required shadow quantities obtained for model 03 before and after correction

Month	Shadow required	Shadow obtained		conformity	
		Before correction	After correction	Before correction	After correction
March	43.33%	15%	12%	No	No
June	100%	15%	35%	No	Yes
December	0.00%	7%	5%	No	Yes

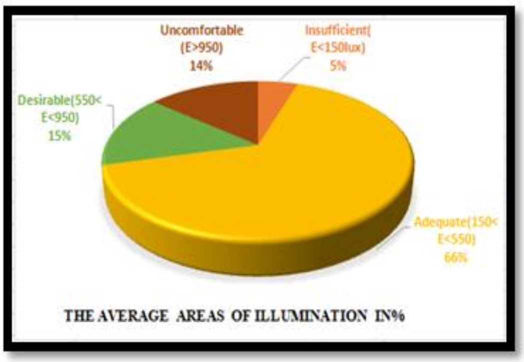
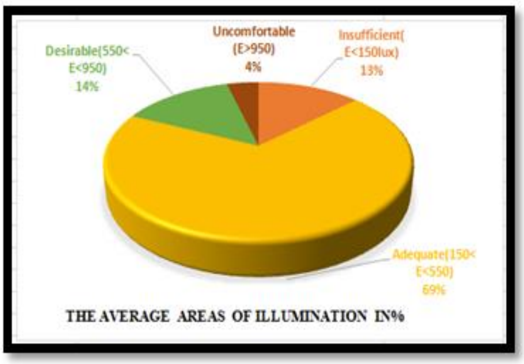
5.2. Interpreting results in lighting performance

Model 01 before and after the correction

- Horizontal sunshade resizing (awning) helped to reduce the average illuminance surface that presents the discomfort with 10% difference compared to the model before the correction. This was a reason for reducing the risk of direct glare caused by the surface of the sunspot near the window and especially at noon (reduction of the area of the sunspot from 4.57m² to 1.60m²).

- Almost an increase of 8% in the area of insufficient illuminance in the model after correction from before correction. This is due to the increased length of the awning, which gives the space a feeling of darkness especially at sunrise.
- The model maintained the same values of adequate illumination without and with correction with a percentage of 66%. (Table.16)

Table 16. Percentage of illumination areas in model 01 before and after correction during the year.

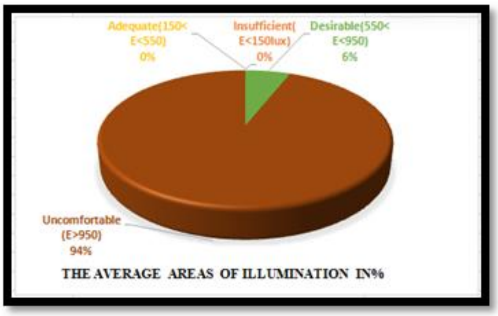
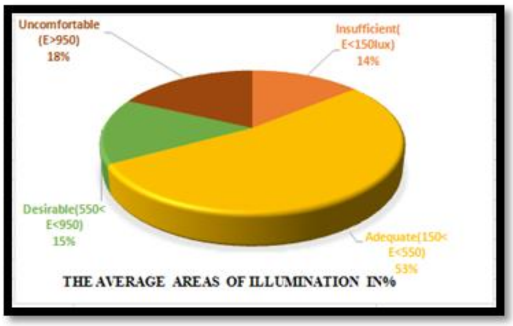
Performance in lighting (level of illumination)		

Model 02 before and after the correction

-The addition of the Light shelf helped to reduce the average area of illumination which presents the discomfort with 76% of difference compared to the model before the correction. This has been a reason for reducing the risk of direct glare caused by the surface of the sunspot near the window and especially at noon.

- Almost an increase of 09% in the desired illumination area in the front model before correction from after the correction.
- The model maintained has an adequate illumination value of 53% with correction compared to a value of 0% in the model without correction. (Table.17).

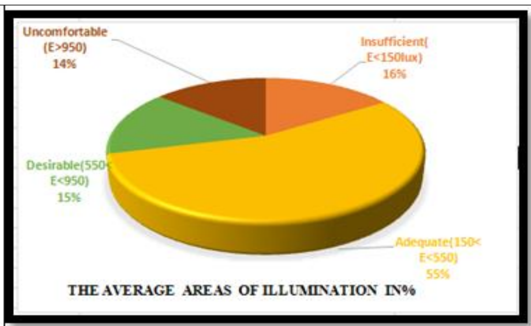
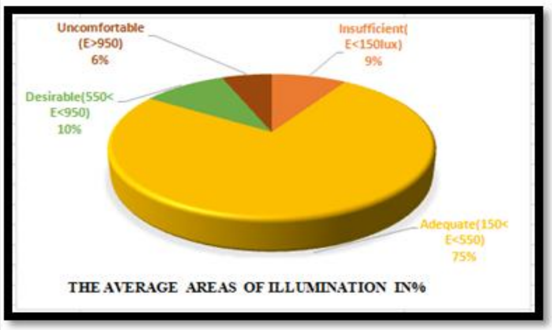
Table 17. Percentage of illumination areas in model 02 before and after correction during the year.

<table>
<tr>
<td>Performance in lighting (level of illumination)</td>
<td>
</td>
<td>
</td>
</tr>
</table>

Model 03 before and after the correction

- The LGS decreased the area that had an illuminance level greater than 950 lux from 14% to 6%, as well as, reducing the average level of insufficient illumination from 16% to 9%.
- The blind provides a good distribution of illumination in the office or it is found that the adequate illuminance surface is high from 55% to 75%. (table.18).

Table 18. Percentage of illumination areas in model 03 before and after correction during the year.

<table>
<tr>
<td>Performance in lighting (level of illumination)</td>
<td>
</td>
<td>
</td>
</tr>
</table>

6. Conclusion

This paper presents the main results of an experimental work consecrate to highlight one of the elements that has received considerable attention in today's architecture: the window. More specifically, the study focused on the evaluation of the impact of window wall ratio and shading devices on the thermal and visual interior quality in work spaces using 03 models of offices located in hot and arid zone and exactly in the city of Biskra , oriented South and extracted after an analytical study. Those 03 models have different WWR and different un-studied shading devices. We studied each model after and before a corresponding correction.

Concerning thermal performance, and because the interdisciplinary of this field we decided to choose the Shading Coefficient, as the only variable to adapt to the study. The obtained result confirm that for an office space oriented south: Since its solar benefits can be beneficial in winter, when the building must be heated, providing free heat and are untimely in summer, causing overheating and therefore discomfort:

Appropriate sunscreens for the south orientation for the three models after the correction show almost identical results. This is because of the occultation angle obtained for the south orientation; which from the point of view of solar geometry, returns strictly to the same.

Despite the qualifying positive optimization for the appropriate protections, however, it seems that it is satisfactory compared to the required shade value from the Novell method for certain month:

For model 01: the shading values obtained with the correct dimensions of a combined solar shading canopy and awning, using in an office with WWR= 15% are approached to the required values which is favorable.

For the 02 model: the integration of the light shelf system in an office with WWR= 60% gives confirmed shading values just for the months of March and June, which is favorable for a hot climate

For model 03: the addition of a light guide blind in an office with WWR= 10% gives shading values confirmed just for the month of March and June which is desirable for the hot period.

About lighting performance, also and because of the complexity of the phenomenon of natural light, the study will be limited to studying the performance of a single physical parameter that is the illumination received on the work plan in an office.

Compared to reference values, all solar breeze systems adapted to the three models with different opening ration have a better natural lighting performance compared to the models before the correction.

Regarding the average areas of adequate illumination, the three models after the correction give preferable values more than 60% compared to the models before the correction.

All corrected models have average areas of illumination that are uncomfortable than those obtained in uncorrected models with a reduction ratio of 1/3.

To conclude, when choosing to integrate windows for any space, all elements specific to the interior efficiency cannot be fulfilled in a compatible way. Whose purpose remains proportional depending on the shape, size and characteristics of the window and the space itself.

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