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Daylight Efficiency development Strategies in The Southern Interior Spaces of Administrative Buildings
Case study - Clean water and Sewage building in Dakahlia

Noura Ahmed Soliman Hashim and Ahmed El-Tantawy

KEYWORDS:

Daylight simulation software, Shading systems, Daylight performance, Window – to - Wall Ratio (WWR), Office building.

Abstract— **Daylighting is one of the most important affairs because of its importance in saving energy consumption and visual comforts inside space for occupants. The research aims to study the effect of changing the Window-to-Wall Ratio (WWR), and using horizontal shading devices for the southern spaces of Clean Water and Sewerage building in Dakahlia to improve daylighting performance in the office buildings. This methodology is carried out in four phases: The first phase, study of the current condition of daylighting level in the southern space. The second phase, reducing the number of windows. The third phase, parametric analysis for WWR values. Fourth phase, parametric analysis for horizontal shading devices. The implementation of the simulation process is carried out by using the Grasshopper for Rhino software, which supports simulation parametric model process and the use of Ladybug & Honeybee for Grasshopper tools, which were used to improve daylighting performance in the southern office spaces where daylighting is insufficient. The simulation process performed by using spatial Daylight Autonomy (sDA 300/50%) and Annual Sunlight Exposure (ASE 1000/250) metrics with integration of LEED V4.1 criteria. Results demonstrated that the effect of changing WWR values on daylighting performance inside the space. The research is recommended to using horizontal shading devices as they achieve the required values of sDA and ASE according to LEED V4.1 criteria and achieve glare DGP inside the southern space, so that the occupant does not have to close the windows and rely on artificial lighting and thus increase energy consumption.**

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Corresponding Author: *Noura Ahmed Soliman Hashim, researcher at Faculty of Engineering, Mansoura University, Architectural Engineering, (e-mail: eng_noura89@hotmail.com).*

Assoc. Prof. Dr. Ahmed El-Tantawy, Associate professor and Head of the Department of Architectural Engineering at Faculty of Engineering, Mansoura University, (e-mail: Eltantawy_A@mans.edu.eg)

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I. INTRODUCTION

THE recent escalation of the energy crisis in the Arab Republic of Egypt is an important motive for saving energy consumption and attention to a new and renewable energy, especially in the case of providing the available resources in Egypt. Egypt occupied the second wide in the world after the United States of America in the ranking of most countries in the world that the longest period of sunshine throughout the year [1]. Daylighting is one of the main influencing factors in sustainable architecture and improving energy efficiency in buildings in general and administrative buildings in particular. Daylighting will have both economic and environmental benefits [2]. Further, daylighting has the potential to improve human health, mood, performance, and productivity [3]. The main factor of carbon emission in the building is electrical energy consumption [4]. Today, a large amount of energy is consumed to provide illumination for the interior space and reduce the heat emitted from artificial lighting, while optimal use of daylighting can reduce the energy consumed for cooling and air conditioning [5]. European studies on energy consumption show that buildings are responsible for more than 30% of energy use and less than 40% of carbon dioxide emissions [6]. Daylight gets about 110 lm/Watt of sun radiation, while fluorescent lamps provide about 75 lm/ watt of electrical input and incandescent lamps nearly 20 lm/watt [7]. More than 20% and less than 60% savings in lighting can be achieved through optimal use of daylight [8]. At best circumstance, systems of active and passive that use daylighting and control components are known to reduce lighting energy consumption by up to 65% [9]. This is the aim of the control and shading devices for daylighting. The main light source is artificial lighting, leading to the increased use of HVAC systems to remove the associated heat. The energy used for lighting represents up to a third of the electricity consumed in the administrative buildings [10]. Thus the use of solar controls is to obtain a balance between the energy load produced by solar radiation and the minimum required daylighting [11]. Shading systems play a very important role in building energy requirements and thus are of critical importance in sustainable architectural design.

Literature Review Following studies generally summarizes what has been done by previous researchers. Both of Hammad and Abu-Hijleh, 2010 used software to evaluate performance energy consumption of a representative office with external louvers on the southern, eastern and western facades in Dubai. Simulations performed on fixed horizontal louvers showed that optimum stability was −20° for the southern facade with an overall energy saving of 31.28%. The optimum angle for vertical louvers on the eastern and western facades was 20° and resulted in a total energy savings of 26.08% and 25.97% on the eastern and western facades, respectively [12]. Stazi and colleagues, 2014 studied shading devices through analyzing the effect of different materials adoption, length of slats and vertical distance between slats [13]. Datta, 2001 analyzed the effect of fixed horizontal louvers on the thermal performance of the building for Italian climates, considering a simple 2-zone building with high external wall U-value; the study focused on the shading device applied to the window on the southern façade [14]. Palmero-Marrero and Oliveira, 2010 investigated the effects of shading devices applied to a building for different climates, and evaluated their effect on indoor thermal conditions and energy demand compared to a building without shading devices [15]. The purpose of this study is to determine the dimensions of the appropriate WWR and the number of louvers for the southern administrative space that affect the performance of daylighting during the year by using daylighting simulation programs in the building of clean water and Sewage companey in Dakahlia. The study will solve the following questions; How does changing WWR values affect the daylighting of the southern office space in the building?, Do the horizontal louvers affect the average annual daylighting performance?, Does the possibility of glare reduced by using horizontal louvers?.

The Aim of Research *is* to develop sustainable design standards for the design of interior spaces for administrative buildings in order to improve the daylighting inside administrative spaces without affecting their functional performance, by using various shading devices of administrative spaces by using digital design tools, including the evaluation of the proposed shading devices through Simulation Tools (Ladybug & Honeybee).

Research Problem _ lies in the presence of some problems in the interior spaces of administrative buildings, which affects the efficiency of the performance of the space occupants, because we find in the applications of architecture and interior that sustainability is not considered into consideration when designing the spaces of administrative buildings, and therefore there is a gap between the design process and the application of sustainability concepts in Designing administrative buildings where the gap lies in achieving sustainability standards in the design of interior spaces for administrative buildings in Egypt, especially daylighting, since it is one of the most important elements of the quality of the interior environment for administrative spaces.

Research Importance _ lies in that it contributes to the achievement of visual considerations when designing the southern interior space of the administrative building, the most important of which is daylighting that provides psychological stability for humans, and there is no doubt that the agreement to improve daylighting conditions is very feasible and quick to compensate financially and psychologically.

II. Research Methodology

The study's methodology based on simulation research strategy which tries to recreate some aspect of the physical environment in one of a variety mode, from a digital simulation software to real scale conditions imitation [16]. This study investigate the performance of daylighting for the interior space of southern office in the building of Clean water and Sewage company in Dakahlia and develops proposals to solve the problems of daylighting for southern interior spaces, by using daylight simulation software.

A. Case study design

Figure 1: Clean water and Sewage building in Dakahlia
source: Author

The building of clean water and Sewage Company in Dakahlia was chosen as the study case for several reasons:

1. Mansoura City combines the character of large cities as it is the capital of Dakahlia Governorate, and the rural character due to what many centers and villages follow.
2. The company's building represents most of the government administrative buildings in Egypt in general, and the administrative work space in particular.
3. It should help the assessment and improvement of the existing building to save energy and provide the quality of the internal environment for the current users, in addition to recommending sustainable design guidelines for future buildings.

Figure 2: satellite Map for Clean water and Sewage building in Dakahlia
Source: (Google Earth, 2019)

The building is located in Mansoura City on the Ring Road, at the end of the Al-Obour housing, the abattoir, and Dakahlia, where it is located next to it to the west of the building of the Central Sewage Laboratory.

B. Case study design

The building consists of seven floors with an area of 785 square meters, and the building contains a main entrance and is located in the south, and a side entrance is located in the east, as shown in figure 3.

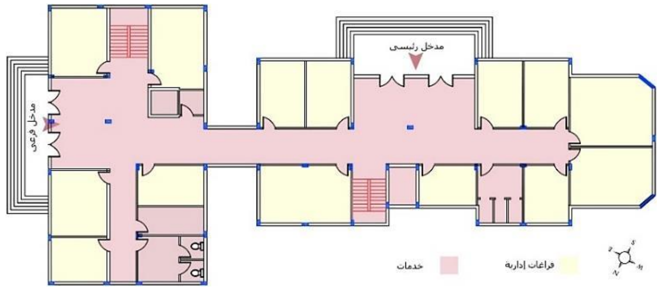


Figure 3: Architectural details of the building (Ground Floor)
source: Author

C. Basic information of the case study

TABLE I
BASIC INFORMATION OF THE CASE STUDY

Project Site	Mansoura, the end of Masaken Al-Obour, the Ring Road, The Slaughterhouse, Dakahlia, Egypt
Architectural and Construction Office	Al-Shaer Consult, Talkha, the new bridge
Project Type	Administrative (Public Business Sector)
Total Floor Area	785 m^2
No. of employees	7000 employees
Project Completion Date	2004

D. Case study description

This research will focus on studying the southern space of the administrative building, since the southern space is the most exposed space to solar radiation during the building's working period, as the southern space is located on the third floor of the building.

Figure 4: The current model of the building of Clean water and Sewage company in Dakahlia by using Revit® BIM
source: Author

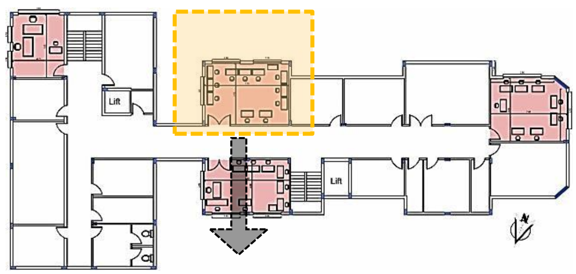


Figure 5: Southern office space plan that is being studied in this research by using Autodesk AutoCAD software
source: Author

E. *Southern Space Design*

It was designed with an area of 43.68 m^2, an internal height of 3m, 7.8m long, 5.6 m width. The external walls are 0.25m thick, the internal walls are 0.12m thick, and the ceiling and floor are 0.15m thick for each of them. External windows 2.6m width and 1.3m high, which are sliding windows, as shown in figure 6.

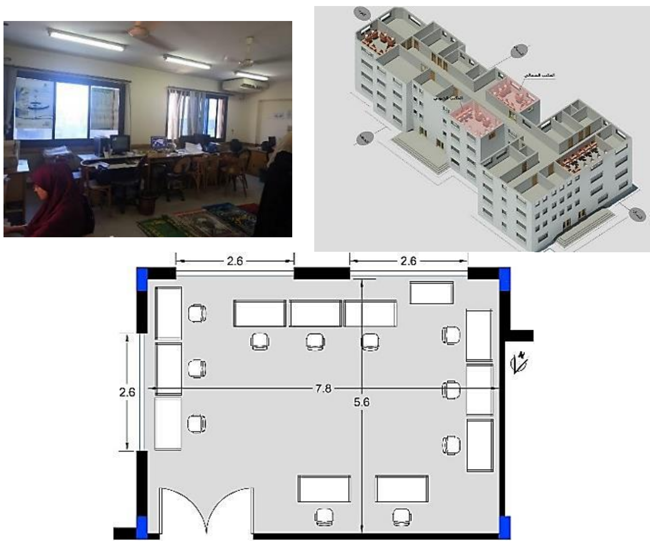


Figure 6: The architectural details for the Southern office space plan source: Author

III. DAYLIGHT SIMULATION SOFTWARE

Daylight simulation is one of the most significant analysis in sustainable architecture designing process. Here, Grasshopper for Rhino and Ladybug & Honeybee for Grasshopper software are used because of the progressive facilities and accessibility to a comprehensive collection of daylight and visual comfort analysis [17]. Ladybug is used to produce a visual visualization of the climate & its analysis [18]. Honeybee is used to simulate temperature, lighting, and use of different scales [19].

IV. METRICS OF DAYLIGHTING

The daylight illuminance levels were measured using a group of dynamic metrics as follow.

A. *Spatial Daylight Autonomy (sDA 300 ⁄ 50%):*

It is one of the Annual Metrics that describes the sufficiency of daylight illuminance levels inside space. It is defined as a ratio of space area which achieves a daylight level not less (300 lux) for total time not less (50%) of space occupation hours throughout the year so it known as (sDA 300 ⁄ 50%) [20].

B. *Annual sunlight exposure (ASE 1000 ⁄ 250):*

A metric describes excessive sun exposure, and describes the expected visual discomfort inside work environment. It is defined as a ratio of area of space that the direct illumination level rises over a (1000 lux) in zero bounces case, for total time more than (250 hours) of the total occupancy hours so it is known as (ASE 1000 ⁄ 250) [21].

V. SIMULATION PROCESS STEPS

The following table shows simulation process steps:

TABLE 2
CONCLUSION FOR SIMULATION PROCESS STEPS

Modelling of building: for the administrative space with variables of length, width and height.			
length	Fixed		7.8m
width	Fixed		5.6m
height	Fixed		3m
Opening configuration: with variables of number of windows, sill height, window height and width.			
Direction	Fixed		south
NO. of Windows	Variable		-
Sill height	Fixed		0.9m
Window width	Variable		-
Window height	Variable		-
Materials definition: Walls, Ceilings, Floors and Windows			
Walls reflection	Fixed		0.5
ceilings reflection	Fixed		0.8
Floors reflection	Fixed		0.2
Windows transmission	Fixed		0.6
Work surface definition: with a variable of hight from the ground surface and the distance between the sensors.			
Work surface height	Fixed		0.9
distance between the sensors	Fixed		0.6
Run the simulation: with location variables, sky condition, light illuminance, and working hours.			
Location	Fixed		Mansoura, Dakahlia, Egypt
sky condition	Fixed		Clear sunny sky
working hours	Fixed	First of the day	8 am
	Fixed	End of the day	3 pm
Time map during the year	Fixed	The first working day	1 January
	Fixed	The last working day	30 December
	Fixed	weekend	Friday and Saturday

VI. METHODOLOGY OF EVALUATING STEPS SIMULATION ANALYSIS

The following simulations analysis were made at three levels of evaluation. The three evaluations were done as daylight simulation analysis (with lighting criteria illustrated in table 3) [22].

TABLE 3
CONCLUSION FOR LIGHTING CRITERIA USED IN EVALUATION OF SIMULATION RESULTS

Lighting Criteria	
Target Illuminance	300 lux
ASE	Must be less than 10 preferred ratio less than 7 and the best case less than 3
sDA	>55 – 2 points on LEED >75 – 3 points on LEED
DGP	<35 imperceptible glare- 35>DGP<45- perceptible glare

1- sDA and ASE Analysis was done for the tested parameters to get the cases which achieve sufficient daylight and get the points on the LEED rating system.

TABLE 4
THE KEY LEGEND FOR CASES CLASSIFICATION ACCORDING TO LEED RATING SYSTEM

Classification according LEED V4.1	**Refused**		**Accepted**			
	Due to ASE	Due to sDA	2 points on LEED	3 points on LEED		
			ASE < 10	ASE < 10	ASE ≤ 7	ASE ≤ 3
Color legend						
Classification criteria	ASE > 10	sDA < 55	55 < sDA ≤ 75	sDA ≥ 75		

2- Daylight availability was analyzed for the successful cases at the previous step, and then the best performance cases which achieved the maximum daylit and minimum partially daylit were chosen from the following performance to continue with other evaluations steps.

TABLE 5
CONCLUSION FOR DAYLIGHT AVAILABILITY

Low Performance	50%≤ daylit area <65%
Medium Performance	65%≤ daylit area <75%
High Performance	75%≤ daylit area

3- Glare analysis at 8:00 am and 12:00 pm in the different seasons of summer/winter solstices and autumn equinox (21 of March, 21 of June and 21 of December) was done to the high performance cases from the previous steps and the best cases which achieved minimum imperceptible glare were chosen for the last evaluation step [23].

TABLE 6
CONCLUSION FOR GLARE ANALYSIS

intolerable glare	DGP ≥ 45%
disturbing glare	45% > DGP ≥ 40%
perceptible glare	40% > DGP ≥ 35%
imperceptible glare	DGP < 35%

VII. THE METHODOLOGY USED IN THE ANALYSIS PROCESS OF THE SOUTHERN SPACE

The methodology is carried out in four phases:

The first phase: *Study the current condition of the level of daylighting in the southern space, and evaluate it according to LEED V4.1 standard.*

A. SDA and ASE results

TABLE 7
THE SOUTHERN SPACE ANALYSIS ACCORDING TO LEED V4.1 STANDARDS WITHOUT ANY SHADING DEVICES

Performance	**WWR South**	**WWR East**
	29%	23%
sDA	100%	
ASE	62%	
LEED V4.1 Rating		

The ASE value did not achieve the LEED V4.1 standard, because it is more than 10%, and this indicates that the solar radiation is high inside the southern space.

B. Daylight Availability results

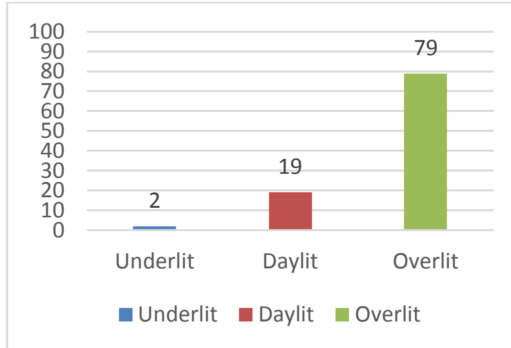


Figure 7: Daylight availability results without any shading devices source: Author

The percentage of daylit is less than 50%, this did not achieve the required percentage, and that the percentage of Overlit is high in the southern space.

C. DGP results

Glare was unacceptable at this phase, due to the presence of an intolerable and disturbing glare within the space.

The second phase: *Reducing the number of windows in space, given that its area is small, does not require making windows in two directions and only one direction is sufficient, and then evaluating them according to LEED V4.1 standard.*

A. SDA and ASE results

TABLE 8
THE SOUTHERN SPACE ANALYSIS ACCORDING TO LEED V4.1 STANDARDS WITHOUT ANY SHADING DEVICES

Performance	**WWR South**
	29%
sDA	100%
ASE	35%
LEED V4 Rating	

The ASE value did not achieve the LEED V4.1 standard, because it is more than 10%, and this indicates that the solar radiation is high inside the southern space.

B. Daylight Availability results

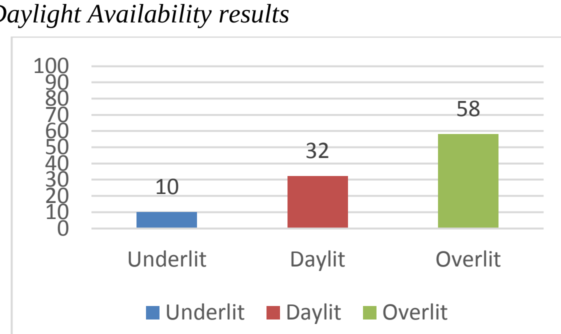


Figure 8: Daylight availability results without any shading devices source: Author

The percentage of daylit is less than 50%, this did not achieve the required percentage, and that the percentage of Overlit is high in the southern space.

C. DGP results

Glare was unacceptable at this phase, due to the presence of an intolerable and disturbing glare within the space.

The third phase: *Parametric analysis for WWR values.*

1) *The Investigated WWR values:*

Twelve values of window sizes, expressed as Window-to-Wall Ratio (WWR) ,were analyzed for each design. These values started from 10% until they reached 65 % at 5% increments. The window started from the middle of the wall with fixed sill height 0.9m. Window height and width are considered the two variable parameters. Figure 9 illustrates the increase in window width in the rest of the investigated WWR from 10% to 40%. Figure 10 illustrates the increase in window height in the first five investigated WWRs from 45% to 65%.

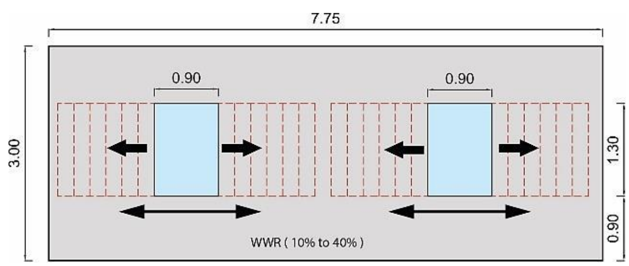


Figure 9: Horizontal Extend for Window to achieve WWR from 10 to 40% at office space parametric model
source: Author

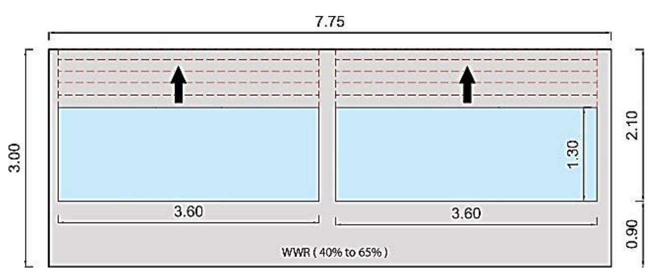


Figure 10: Vertical Extend for Window to achieve WWR from 40 to 65% at office space parametric model
source: Author

2) *WWR Simulation Results at Southern Space:*

A. SDA and ASE Analysis of Investigated WWR:

Simulation results show, the sDA and ASE are directly proportional with the increase of WWRs values, as illustrated in Figure 11. The first threshold for successful cases lies on the 55% sDA. All cases with a WWR larger than 20% reached or exceeded the threshold. In contrast, cases with small windows and a WWR less than 20 % didn't achieve sufficient daylight performance. The second threshold for successful cases lies on the 10% ASE. All cases, achieved unacceptable ASE performances and they overrode the limit. Therefore they also need to be treated with shading devices in the south direction to avoid glare phenomena and achieve sufficient daylight for the southern office space.

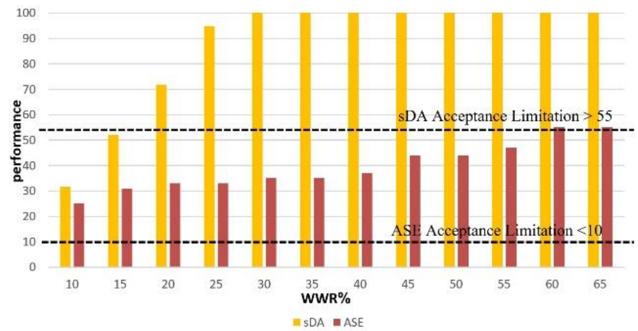


Figure 11: sDA and ASE performance results for the investigated WWR at southern space
source: Author

The fourth phase:

Horizontal louvers: Investigated Louvers Count with Succeed WWR:

Horizontal louvers are added to the southern façade with a thickness of 0.05 m and act as a guide device with reflectivity of 60% and are made of aluminum, so as to reduce the solar radiation during the year inside the space. A simulation of 104 cases was performed at this phase with changing three main variables as follows:

- **The first variable**: is changing window to wall ratio. The cases which achieved 100% sDA in phase three were chosen to investigate its WWR with the second variable. These WWR ranged from 305% till 65% as shown in Table 9.
- **The second variable**: is changing the horizontal louvers slats number. Slats are spaced at a distance that is equal to the slat width so that the slats. The number of louvers ranges from 1 to 9, as shown in Table 10.
- **The third variable**: is changing the angle of the louvers to angles 15^0, 30^0, 45^0, 60^0, as shown in Table 11.

Parametric iterations took place representing all possible combinations of the previous variables resulting in 72 different alternatives. These alternatives were investigated in parametric simulation analysis in order to reach efficient alternatives which achieve sufficient daylight performance.

TABLE 9
ANALYSIS FOR THE INVESTIGATED WWR PARAMETERS

The first variable : The investigated WWR (sample for the investigated WWR with 5 horizontal louvers)

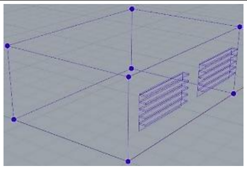
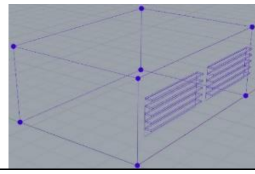
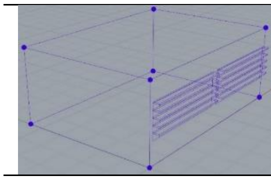
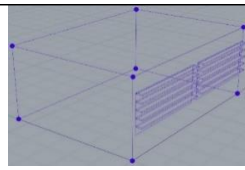
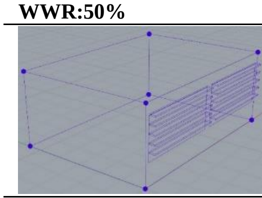
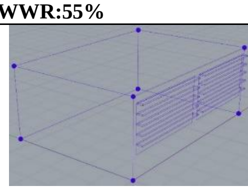
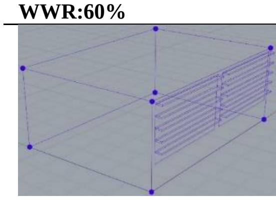
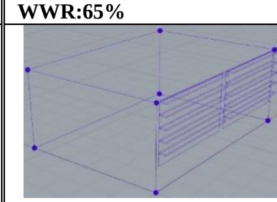
WWR:30%	**WWR:35%**
	
Window size: W= 2.7 m H= 1.3 m	Window size: W= 3.15 m H= 1.3 m
WWR:40%	**WWR:45%**
	
Window size: W= 3.6 m H= 1.3 m	Window size: W= 3.6 m H= 1.47 m
WWR:50%	**WWR:55%**
	
Window size: W= 3.6 m H= 1.64 m	Window size: W= 3.6 m H= 1.8 m
WWR:60%	**WWR:65%**
	
Window size: W= 3.6 m H= 1.96 m	Window size: W= 3.6 m H= 2.1 m

TABLE 10
ANALYSIS FOR THE INVESTIGATED HORIZONTAL LOUVERS COUNT PARAMETERS

The second variable : louvers count
The following sections for different louvers count are used for each investigated WWR

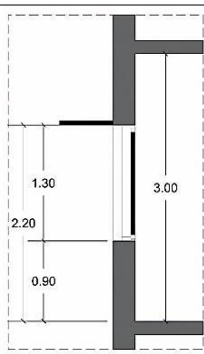
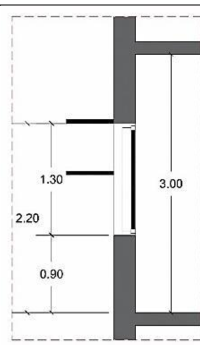
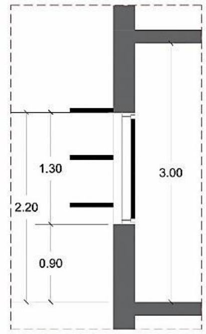
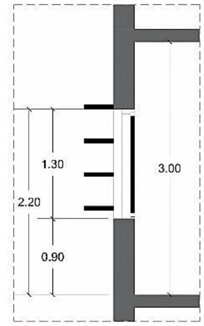
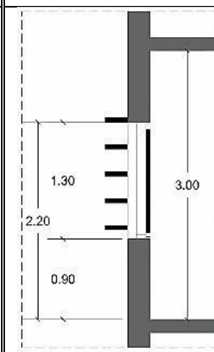
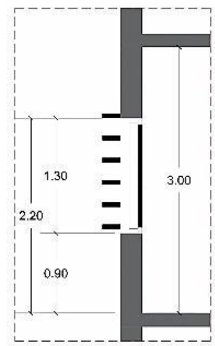
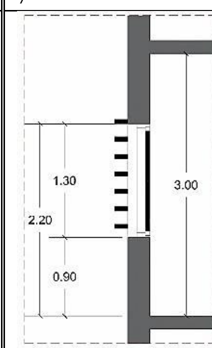
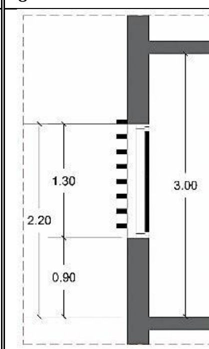
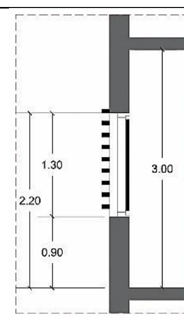
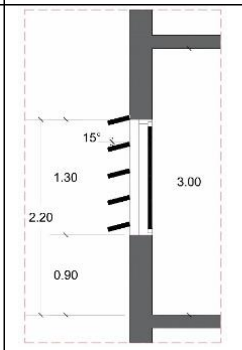
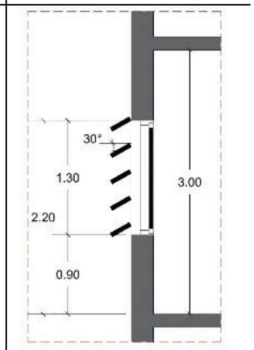
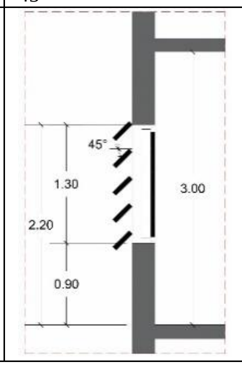
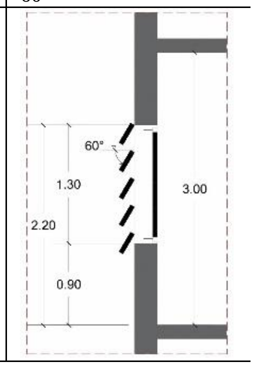
Louvers count	1	2
Section		
Louvers Width/ Distance	0.60 m	0.55 m
Louvers count	3	4
Section		
Louvers Width/ Distance	0.50 m	0.35 m
Louvers count	5	6
Section		
Louvers Width/ Distance	0.25 m	0.2 m
Louvers count	7	8
Section		
Louvers Width/ Distance	0.15 m	0.12 m
Louvers count	9	
Section		
Louvers Width/ Distance	0.10 m	

TABLE 11
ANALYSIS FOR THE INVESTIGATED HORIZONTAL LOUVERS ANGLE PARAMETERS

The third variable: louvers angle The following sections for different louvers angle are used for each investigated WWR

Angle	15^0	30^0
Section		
Angle	45^0	60^0
Section		

1) *Analysis Results: Using horizontal louvers angles 0^o :*

A. SDA and ASE results:

The first threshold for successful cases lies on the 55% sDA. All cases, reached or exceeded the threshold. The second threshold for successful cases lies on the 10% ASE. The cases which have a large louver count (from 4 to 9 louvers) achieved acceptable ASE performance and didn't override the limit. In contrast, the cases with few louver counts, less than 4 slates, are unacceptable except the cases with small WWR (from 45%WWR till 65%) which were acceptable but with high ASE values, as shown in figure 12.

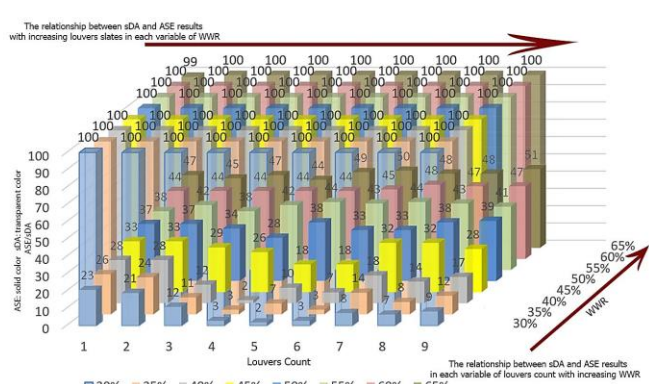


Figure 12:South orientation ASE and SDA results for Investigated Louvers Count and WWRs for angle 0^0
source: Author

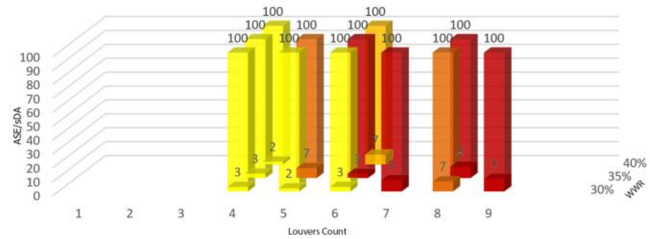


Figure 13: Acceptance according LEED for angle 0^0
source: Author

B. Daylight Availability Analysis of Investigated Accepted Cases:

The simulation results showed as in figure 14, that the best louvers count are 4 slats in WWR 35% and 40%, 6 slats in WWR40%, as in table 6.

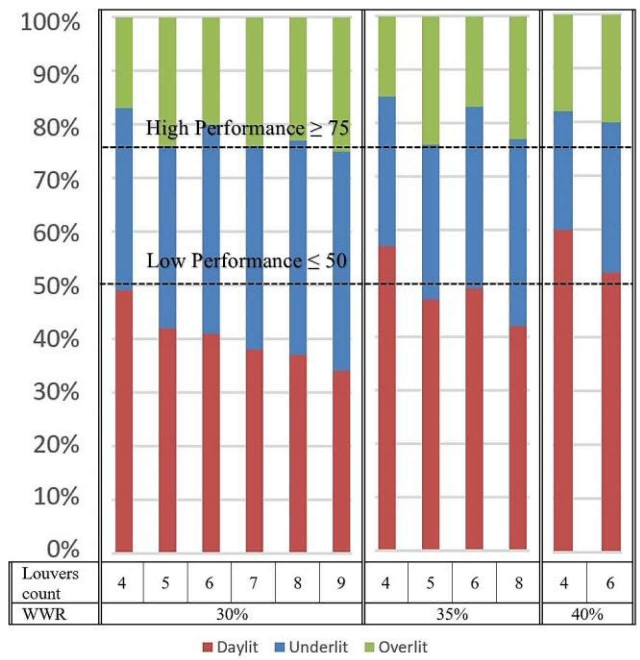


Figure 14: Daylight Availability performance results for the investigated horizontal louvers at south orientation for angle 0^0
source: Author

TABLE 12
EVALUATION FOR DAYLIGHT AVAILABILITY PERFORMANCE FOR USING HORIZONTAL LOUVERS AT SOUTH DIRECTION FOR ANGLE 0^0_ ACCEPTED CASES COLORED BY YELLOW

Louvers Count		4			5			6			7			8			9		
Daylight Availability		U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O
WWR	30%	34	49	17	34	42	24	39	41	20	38	38	24	40	37	23	41	34	25
	35%	28	57	15	29	47	24	34	49	17				35	42	23			
	40%	22	60	18				28	52	20									

C. Glare Analysis for The Top Performance Cases

Glare was unacceptable at this phase, due to the presence of an intolerable and disturbing glare within the space.

✓ This case is unacceptable

2) *Analysis Results: Using horizontal louvers angles 15°:*

A. SDA and ASE results:

The first threshold for successful cases lies on the 55% sDA. All cases, reached or exceeded the threshold. The second threshold for successful cases lies on the 10% ASE. The cases which have a large louver count (from 4 to 9 louvers) achieved acceptable ASE performance and didn't override the limit. In contrast, the cases with few louver counts, less than 4 slates, are unacceptable except the cases with small WWR (from 45%WWR till 65%) which were acceptable but with high ASE values, as shown in figure 15.

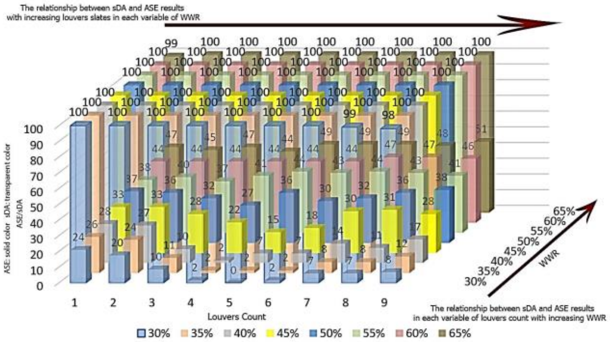


Figure 15:South orientation ASE and sDA results for Investigated Louvers Count and WWRs for angle 15^0
source: Author

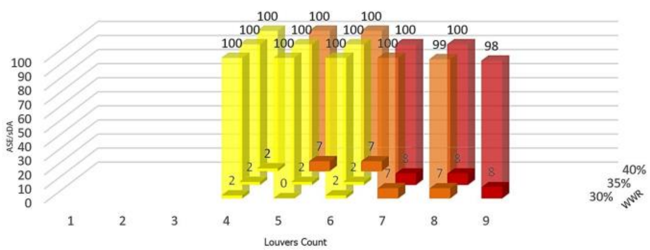


Figure 16: Acceptance according LEED for angle 15^0
source: Author

B. *Daylight Availability Analysis of Investigated Accepted Cases:*

The simulation results showed as in figure 17, that the best louvers count are 4 slats in WWR 35% and 40%, (4, 5, 6) slats in WWR40%, as in table 7.

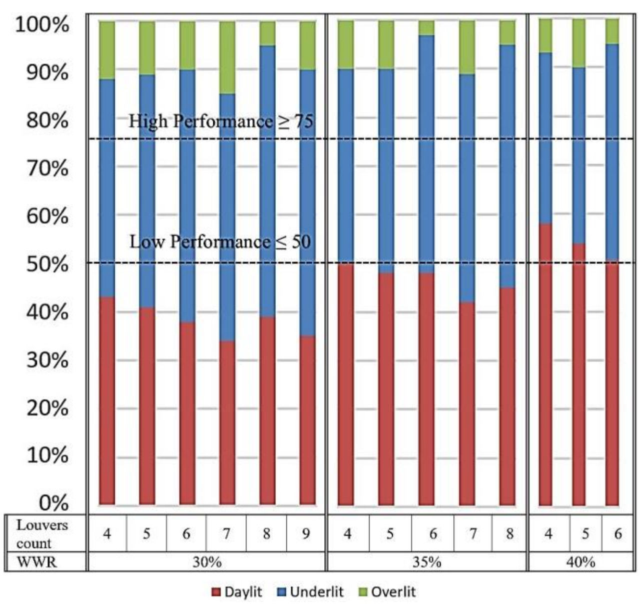


Figure 17: Daylight Availability performance results for the investigated horizontal louvers at south orientation for angle 15^0

source: Author

TABLE 13
EVALUATION FOR DAYLIGHT AVAILABILITY PERFORMANCE FOR USING HORIZONTAL LOUVERS AT SOUTH DIRECTION_ANGLE 15^0_ ACCEPTED CASES COLORED BY YELLOW

Louvers Count		4			5			6			7			8			9		
Daylight Availability		U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O
WWR	30%	45	43	12	48	41	11	52	38	10	51	34	15	56	39	5	55	35	10
	35%	40	50	10	42	48	10	49	48	3	47	42	11	50	45	5			
	40%	35	58	7	36	54	10	42	53	5									

C. *Glare Analysis for the Top Performance Cases:*

Glare was imperceptible at 8:00, 10:00, 12:00 and 2:00 in the different season's (21 March - 21 June - 21 December) as shown in table 8, although there were slight differences in their performance.

TABLE 14
GLARE ANALYSIS FOR THE ONE BEST CASES

WWR=35% - Louvers =4 slats

	21 March	21 June	21 December
8:00 AM			
	Imperceptible DGP 28%	Imperceptible DGP 27%	Imperceptible DGP 30%
12:00 PM			
	Imperceptible DGP 30%	Imperceptible DGP 27%	Imperceptible DGP 32%

3) *Analysis Results: Using horizontal louvers angles 30^o :*

A. *SDA and ASE results:*

The first threshold for successful cases lies on the 55% SDA. All cases, except one case with 30% WWR and 9 slate, reached or exceeded the threshold. The second threshold for successful cases lies on the 10% ASE. The cases which have a large louver count (from 3 to 9 louvers) achieved acceptable ASE performance and didn't override the limit. In contrast, the cases with few louver counts, less than 3 slates, are unacceptable except the cases with small WWR (from 45%WWR till 65%) which were acceptable but with high ASE values, as shown in figure 18.

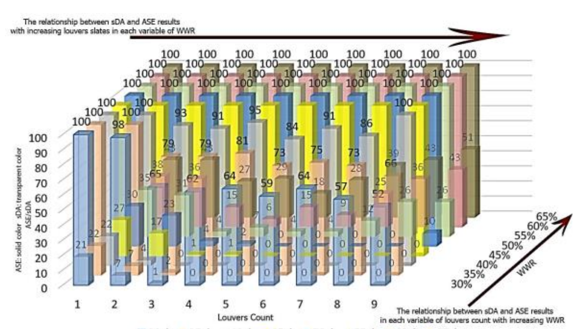


Figure 18:South orientation ASE and sDA results for Investigated Louvers Count and WWRs for angle 30^0

source: Author

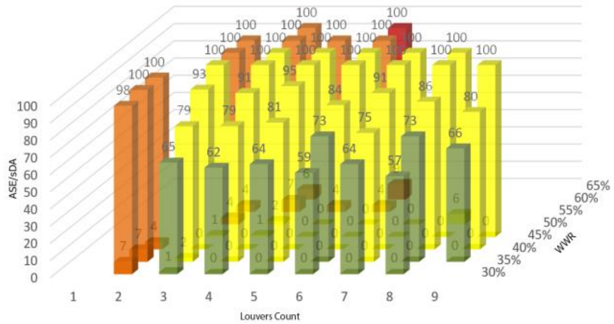


Figure 19: Acceptance according LEED for angle 30^0
source: Author

B. *Daylight Availability Analysis of Investigated Accepted Cases:*

The simulation results showed in figure 20, that the best louvers count are 2 slat in WWR 35% and 40%, (3, 4, 5,6,8,9) slats in WWR 45%, (3, 4, 5,6,7,9) slats in WWR 50%, (3, 4, 5,6) slats in WWR 55%, (4,6) slats in WWR 60% as in table 9.

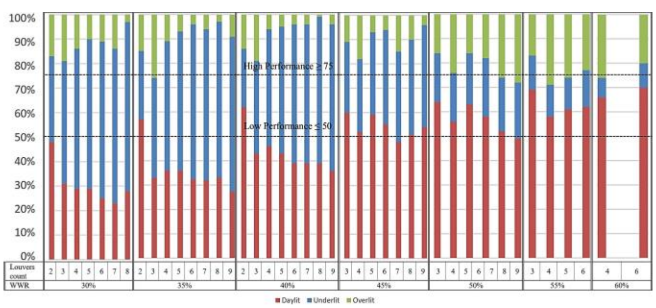


Figure 20: Daylight Availability performance results for the investigated horizontal louvers at south orientation for angle 30^0
source: Author

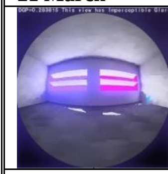
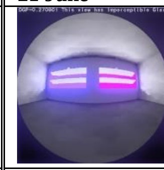
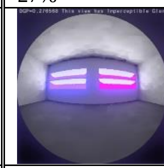
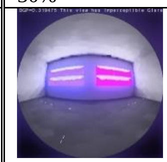
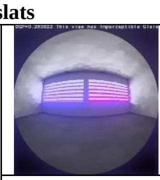
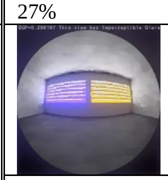
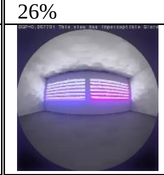
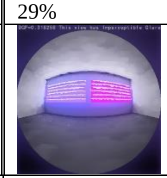
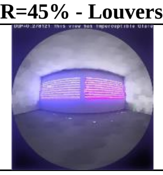
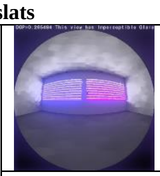
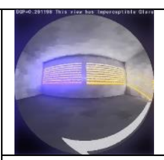
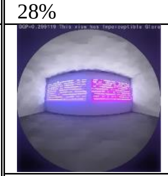
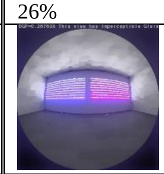
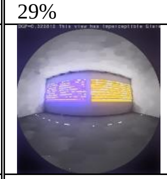
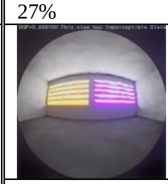
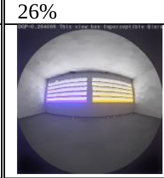
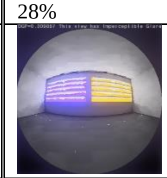
TABLE 15
EVALUATION FOR DAYLIGHT AVAILABILITY PERFORMANCE FOR USING HORIZONTAL LOUVERS AT SOUTH DIRECTION_ANGLE 30^0_ ACCEPTED CASES COLORED BY YELLOW

Louvers Count	2			3			4			5			6			7			8			9		
Daylight Availabilit	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O
WWR 30%	35	48	17	50	31	19	57	29	14	61	29	10	64	25	11	63	23	14	69	28	3			
35%	28	57	15	41	33	26	53	36	11	57	36	7	63	32	4	62	32	6	64	33	3	63	27	9
40%	24	62	14	38	43	19	48	46	6	52	43	5	57	39	4	57	39	4	60	39	1	60	36	4
45%				29	60	11	30	52	18	34	59	7	39	55	6	37	48	15	39	51	10	42	54	4
50%				20	64	16	30	56	24	21	63	16	24	58	18	22	52	26	23	49	28	24	50	26
55%				14	69	17	13	58	29	13	61	26	15	62	23									
60%							8	66	26				10	70	20									

C. *Glare Analysis for the Top Performance Cases:*

Glare was imperceptible at 8:00, 10:00, 12:00 and 2:00 in the different season's (21 March - 21 June - 21 December) as shown in table 10, although there were slight differences in their performance.

TABLE 16
GLARE ANALYSIS FOR THE FOUR BEST CASES

	21 March	21 June	21 December
WWR=35% - Louvers =2 slat			
8:00 AM	 Imperceptible DGP 28%	 Imperceptible DGP 27%	 Imperceptible DGP 30%
12:00 PM	 Imperceptible DGP 30%	 Imperceptible DGP 28%	 Imperceptible DGP 32%
WWR=45% - Louvers =6 slats			
8:00 AM	 Imperceptible DGP 27%	 Imperceptible DGP 26%	 Imperceptible DGP 29%
12:00 PM	 Imperceptible DGP 30%	 Imperceptible DGP 27%	 Imperceptible DGP 32%
WWR=45% - Louvers =9 slats			
8:00 AM	 Imperceptible DGP 28%	 Imperceptible DGP 26%	 Imperceptible DGP 29%
12:00 PM	 Imperceptible DGP 30%	 Imperceptible DGP 27%	 Imperceptible DGP 32%
WWR=50% - Louvers =5 slats			
8:00 AM	 Imperceptible DGP 27%	 Imperceptible DGP 26%	 Imperceptible DGP 28%
12:00 PM	 Imperceptible DGP	 Imperceptible DGP	 Imperceptible DGP

	29%	26%	31%

4) *Analysis Results: Using horizontal louvers angles 45°:*

A. SDA and ASE results:

The first threshold for successful cases lies on the 55% sDA. All cases, except more than one case with 30% WWR and 35% WWR and 40% WWR and from (3 to 9) slates, reached or exceeded the threshold. The second threshold for successful cases lies on the 10% ASE. The cases which have a large louver count (from 3 to 9 louvers) achieved acceptable ASE performance and didn't override the limit. In contrast, the cases with few louver counts, less than 2 slates, are unacceptable except the cases with small WWR (from 55%WWR till 65%) which were acceptable but with high ASE values, as shown in figure 21.

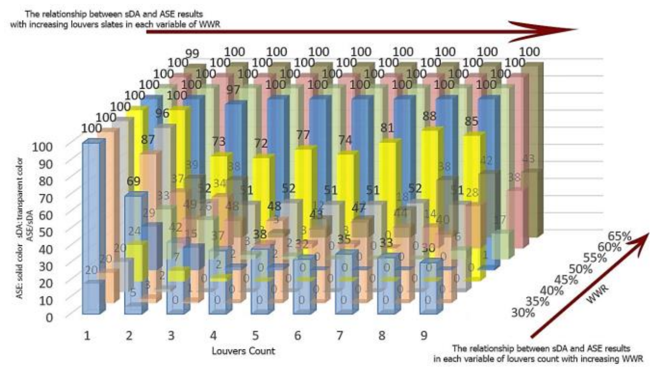


Figure 21:South orientation ASE and sDA results for Investigated Louvers Count and WWRs for angle 45^0
source: Author

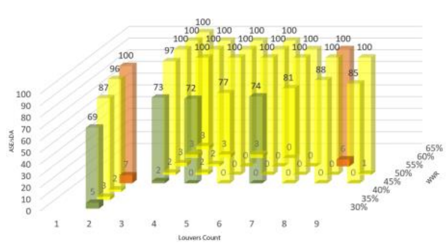


Figure 22: Acceptance according LEED for angle 45^0
source: Author

B. Daylight Availability Analysis of Investigated Accepted Cases:

The simulation results showed as in figure 23, that the best louvers count are 2 slat in WWR 45%, 5 slats in WWR 50%, (3, 5, 6,7,8) slats in WWR 55%, (2, 4, 5,6) slats in WWR 60%, 3 slats in WWR 65% as in table 11.

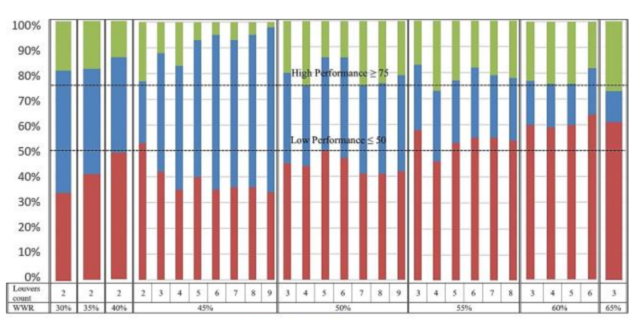


Figure 23: Daylight Availability performance results for the investigated horizontal louvers at south orientation for angle 45^0
source: Author

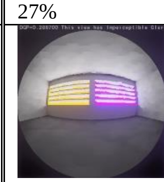
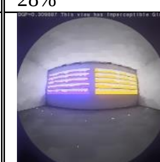
TABLE 17
EVALUATION FOR DAYLIGHT AVAILABILITY PERFORMANCE FOR USING HORIZONTAL LOUVERS AT SOUTH DIRECTION_ANGLE 45^0_ ACCEPTED CASES COLORED BY YELLOW

Louvers Count	2			3			4			5			6			7			8			9		
Daylight Availability	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O
WWR 30%	47	34	19																					
WWR 35%	42	42	16																					
WWR 40%	37	49	14																					
WWR 45%	24	53	23	46	42	12	48	35	17	53	40	7	60	35	5	57	36	7	59	36	5	64	34	2
WWR 50%				35	45	20	31	44	25	36	50	14	39	47	14	34	41	25	35	41	24	37	42	21
WWR 55%				25	58	17	27	46	27	24	53	23	27	55	18	24	55	21	24	54	22			
WWR 60%				17	60	23	17	59	24	16	60	24	18	64	18									
WWR 65%				12	61	27																		

C. Glare Analysis for the Top Performance Cases:

Glare was imperceptible at 8:00, 10:00, 12:00 and 2:00 in the different season's (21 March - 21 June - 21 December) as shown in table 12, although there were slight differences in their performance.

TABLE 18
GLARE ANALYSIS FOR THE ONE BEST CASES
WWR=50% - Louvers =5 slats

	21 March	**21 June**	**21 December**
8:00 AM			
	Imperceptible DGP 27%	Imperceptible DGP 26%	Imperceptible DGP 28%
12:00 PM			
	Imperceptible DGP 29%	Imperceptible DGP 26%	Imperceptible DGP 31%

5) ***Analysis Results: Using horizontal louvers angles 60⁰ :***

A. sDA and ASE results:

The first threshold for successful cases lies on the 55% sDA. All cases, except more than one case with 30% WWR and 35% WWR and 40% WWR and from (3 to 9) slates, reached or exceeded the threshold. The second threshold for successful cases lies on the 10% ASE. The cases which have a large louver count (from 3 to 9 louvers) achieved acceptable ASE performance and didn't override the limit. In contrast, the cases with few louver counts, less than 2 slates, are unacceptable except the cases with small WWR (from 50%WWR till 65%) which were acceptable but with high ASE values, as shown in figure 25.

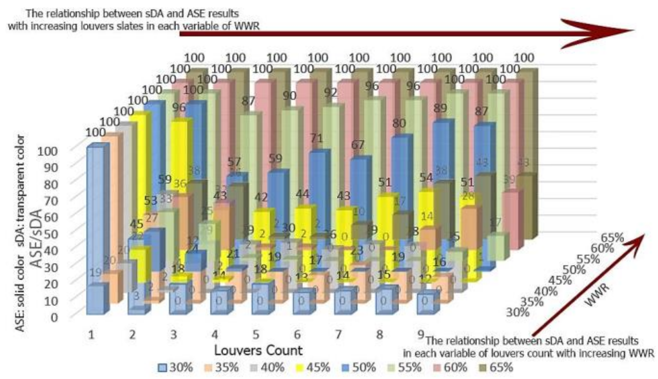


Figure 25:South orientation ASE and sDA results for Investigated Louvers Count and WWRs
source: Author

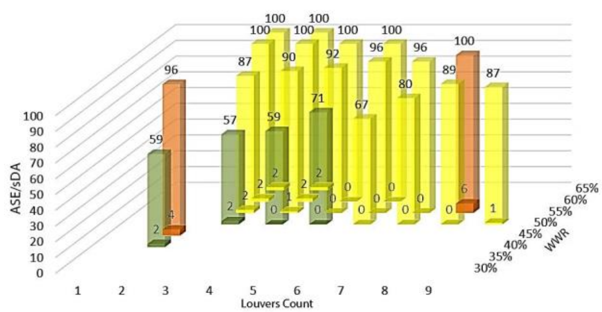


Figure 26: Acceptance according LEED
source: Author

B. *Daylight Availability Analysis of Investigated Accepted Cases:*

The simulation results showed as in figure 27, that the best louvers count are 6 slats in WWR 60%, 4 slats in WWR 65% as in table 13.

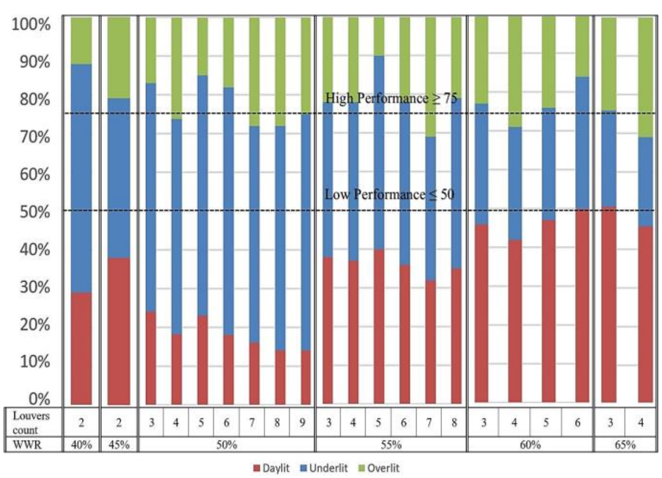


Figure 27: Daylight Availability performance results for the investigated horizontal louvers at south orientation
source: Author

TABLE 19
EVALUATION FOR DAYLIGHT AVAILABILITY PERFORMANCE FOR USING HORIZONTAL LOUVERS AT SOUTH DIRECTION_ANGLE 30^0_ ACCEPTED CASES COLORED BY YELLOW

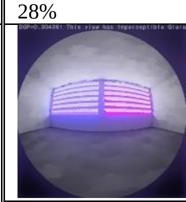
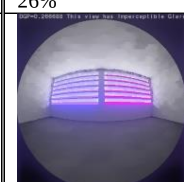
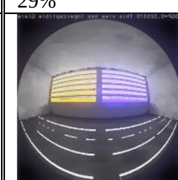
Louvers Count		2			3			4			5			6			7			8			9		
Daylight Availability		U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O	U	D	O
WWR	40%	59	29	12																					
	45%	41	38	21																					
	50%				59	24	17	55	18	26	62	23	15	64	18	18	56	16	28	58	14	28	61	14	25
	55%				44	35	21	37	32	31	42	36	22	50	40	10	41	37	22	40	38	22			
	60%				31	46	23	29	42	29	29	47	24	34	50	16									
	65%				23	46	31	25	51	24															

C. *Glare Analysis for the Top Performance Cases:*

Glare was imperceptible at 8:00, 10:00, 12:00 and 2:00 in the different season's (21 March - 21 June - 21 December) as shown in table 14, although there were slight differences in their performance.

TABLE 20
GLARE ANALYSIS FOR THE ONE BEST CASES

WWR=50% - Louvers =5 slats

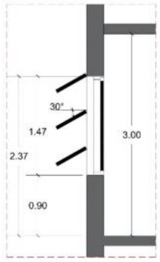
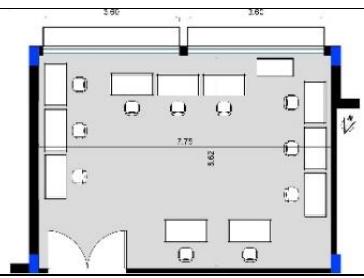
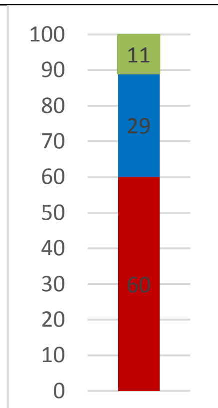
	21 March	21 June	21 December
8:00 AM	 Imperceptible DGP 28%	 Imperceptible DGP 26%	 Imperceptible DGP 29%
12:00 PM	 Imperceptible DGP 30%	 Imperceptible DGP 27%	 Imperceptible DGP 32%

VIII. RESULTS AND RECOMMENDATIONS

RESULTS

The research shows the effect of horizontal shading devices to improve the daylight levels in office spaces by using parametric simulation tools during a year. The case study is southern space in the building of Clean Water and Sewage Company in Dakahlia and simulation was carried out in Mansoura. The results of the analysis indicate that any changes in the angles, count and depth of the horizontal louvers have a noticeable impact on the amount of daylight received through SDA and ASE values according to LEED V4.1 criteria, Daylight Availability and Glare DGP. According to the results, the optimal case is louvers count 3 slats and angle of louver 30⁰ at WWR 45%, as shown in table 21.

TABLE 21
THE BEST SOLUTION FOR SOUTHERN SPACE

Southern space	
	
Width of window	3.6 m
Hight of window	1.47 m
WWR	45%
horizontal louvers count	3
horizontal louvers angle	30^0
sDA	100%
ASE	1
Daylight Availability	
Glare	Glare was imperceptible at 8:00, 10:00, 12:00 and 2:00 in the different season's (21 March - 21 June - 21 December) as shown in table10, although there were slight differences in their performance.

RECOMMENDATIONS

This research recommended to:

1) The authorities concerned with the architectural and urban development and planning in Egypt must take into account the orientation of the administrative buildings and know their needs from solar radiation according to the geographical areas in Egypt to ensure good daylighting.
2) Using digital design tools represented by simulation tools (Ladybug & Honeybee) based on parametric design, which greatly helped designers and researchers to simulate the behavior of daylighting for interior spaces and evaluate them, as it provides the opportunity to simulate very large numbers of operations within a short period of time after that was difficult because the previous tools are based on fixed cases, and when performing several simulations, it is necessary to create a new model for each case study.
3) Activating the role of daylighting in order to achieve visual comfort for the occupant's space and saving energy consumption rates.
4) The researcher is looking for further development in simulation in general, in the field of simulation software in particular, and in the field of simulation of daylighting in particular, as the future trends of the building physics profession clearly indicate the importance of developing software for researchers and developers that performs specific functions and demands knowledge of new technologies, including Programming languages, algorithms and other promising fields that achieve high efficiency and power in understanding the natural phenomena surrounding us, conducting highly efficient simulations and reaching effective results that provide a better life for the current generations without the stone on future generations in meeting their requirements.

AUTHORS CONTRIBUTION

Author 1 did the following:

1- **Research idea proposal**
2- **Data collection and tools**
3- **Data analysis and interpretation**
4- **Investigation**
5- **Methodology**
6- **Software**

Author 2 did the following:

1- **Research idea development**
2- **Methodology**
3- **Permanent Supervision**
4- **Drafting the article**
5- **Final approval of the version to be published**

The corresponding author is responsible for ensuring that the descriptions are accurate and agreed by all authors.

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Title Arabic:

استراتيجيات تطوير كفاءة الإضاءة الطبيعية للفراغات الداخلية الجنوبية للمبانى الإدارية.

"دراسة حالة – مبنى شركة مياه الشرب والصرف الصحى بالدقهلية"

Abstract Arabic:

تعتبر الإضاءة الطبيعية عاملاً مهماً لما لها من أهمية فى تقليل استهلاك الطاقة ووسائل الراحة البصرية داخل الفراغ للمستخدمين. حيث يهدف البحث إلى دراسة تأثير تغيير قيم الفتحات بالنسبة إلى الحائط WWR ومن ثم استخدام وسائل التظليل الأفقية للفراغات الجنوبية لمبنى شركة مياه الشرب والصرف الصحى بالدقهلية لتحسين أداء الإضاءة الطبيعية فى المبانى الإدارية. وهذه المنهجية تتم على أربع مراحل: المرحلة الأولى، دراسة الوضع الحالى لمستوى الإضاءة الطبيعية فى الفراغ الجنوبى. المرحلة الثانية، تقليل عدد النوافذ ثم تقييمه طبقاً لمعيار LEED V4.1. المرحلة الثالثة، تحليل المحدات الخاصة بقيم الفتحات بالنسبة للحائطWWR. المرحلة الرابعة، تحليل المحددات لأنظمة التظليل الأفقية. حيث يتم تنفيذ عملية المحاكاة باستخدام برنامج Grasshopper for Rhino الذى يدعم عملية نمذجة المحددات و استخدام أداتى Ladybug & Honeybee for Grasshopper، الذى تم استخدامهم لتحسين أداء الإضاءة الطبيعية فى الفراغات الجنوبية الإدارية التى لا تتوفر فيها الإضاءة الطبيعية بشكل كافى. وتم اجراء عملية المحاكاة باستخدام مقاييس التحكم المكانى لضوء النهار spatial Daylight Autonomy (sDA 300/50%) والتعرض السنوى لأشعة الشمس Annual Sunlight Exposure (ASE 1000/250) طبقاً لمعيار LEED V4.1. وتظهر الدراسة مدى تأثير تغيير قيم الفتحات بالنسبة إلى الحائط WWR على أداء الإضاءة الطبيعية داخل الفراغ، يوصى البحث باستخدام وسائل التظليل الأفقية حيث أنها تحقق القيم المطلوبة sDA و ASE طبقاً لمعيار LEED V4.1 وتحقق الوهج داخل الفراغ الجنوبى، وذلك حتى لايضطر المستخدم لغلق الفتحات والاعتماد على الإضاءة الصناعية وبالتالى زيادة الطاقة المستهلكة.