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Effects of window and light shelve configurations on energy consumption and daylight illuminance in classrooms

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Abstract

Light shelves not only create shade but also improve the uniformity of daylight. In addition to saving energy, they can improve the lighting quality of a space. This research work aims to position light shelves and deep windows to enhance energy efficiency and daylight illuminance in classrooms in Abadan (Iran) with hot and dry climates. The Rhino/Grasshopper software and Ladybug/Honeybee plugins are used to model and evaluate visual comfort and EUI. By comparing the types of external, internal, and central shelves, and in different situations of window depth, the following results are obtained: by combined use of light shelves and deep windows: in central light shelves, energy consumption decrease by 20%, and glare effects are reduced by 53.37%. As a result, installing a window in the depth of the wall does not have much effect on reducing energy consumption but to some extent, it controls the intensity of glare. The deep window reduces energy consumption (13%), and using light shelves improves energy performance (14% to 20%). Compared to the base model, the combined light shelves reduce UDI by 20% and glare by 53%, while the inside light shelves reduce UDI by 14% and glare by 30%. Therefore, installing light shelves always reduces glare. However, if the intention is to save energy, the central and external light shelves in the position of the deep window are very useful.

Keywords: *Light Shelves, Deep Windows, EUI, UDLI, Daylight.*

1. Introduction

Recently, energy and environmental problems have led to the development of systems to increase energy efficiency and improve the quality of indoor illumination [1]. However, despite the technological advances in lighting, the quality of illumination produced by daylight is still preferable due to its psychological and physiological effects. In addition to improving the health and well-being of the users, these effects lead to significant energy savings in buildings [2, 3]. Therefore, a fundamental point in the design of daylight control systems is to maximize thermal and visual comfort. Recently, research efforts on daylighting systems have focused on protecting occupants from direct sunlight, as well as improving light distribution. The visual connection to the outside and the perception of daylight as vital factors for human health are practical motivations for using daylight applications [4, 5]. The interior spaces are affected by visual interactions, heat exchange, light transmission, and airflow from the outside through openings [6–12]. Natural light after entering the interior brings many problems, so the daylight design requirements must balance the sufficiency of daylight while preventing increasing building heat [13-15]. While preventing the increase of solar heat and controlling the glare of daylight, the external shading devices improve the performance of the building in terms of energy efficiency and the visual comfort of the residents inside the building [16]. Lighting control systems can reduce the energy consumption of electricity by 20% in general and by 60% in particular conditions [17-19]. Windows and other side light applications can bring daylight into the building. However, the use of traditional daylighting techniques has the problem that they only illuminate the areas close to them effectively. The area that receives the most light is called the daylight area, and is mainly affected by the placement and dimensions of the window [20]. Consequently, the distribution of daylight is not uniform in all areas. In these cases, artificial light should be used as additional support, especially in deep areas, to illuminate the space sufficiently. However, daylighting and shading systems such as overhangs, curtains, and louvers can improve incoming solar radiation [21, 22]. Then the interior can achieve a more balanced distribution of daylight while reducing excessive light near openings [23–25].

Light shelves are considered suitable solutions to control daylight in spaces with side lighting. A light shelf not only creates shade but also improves the uniformity of daylight. In addition to saving energy, light shelves can improve the lighting quality of a space. Light shelves are daylighting systems that consist of a horizontal or inclined surface installed above a window. Therefore, it can act as a shading device that prevents excessive sunlight and, if installed externally, can reduce solar gains. Despite the many functions of light shelves, most reviews have focused on the "performance" of lighting distribution. This performance depends on various parameters such as the prevailing sky conditions, the solar altitude angle, the location of the shelf, and the materials used on its upper surface. Although the external light shelves have better shading possibilities, internal shelves can improve the lighting distribution much better [26–28]. Therefore, the internal or external depth of light shelves affects the shading efficiency or illuminance levels.

Natural daylight, while creating a bright visual environment in educational spaces, improves mental health and well-being; however, daylight can also be undesirable due to excessive glare and heat-increasing characteristics. The need for natural light inside the building and the physical characteristics of natural daylight are vital for the visual quality of the educational space. Therefore, it is important to understand human needs for natural light inside the building, especially in classrooms. The daylight factor for a classroom or educational studio should be in the range of 1.0-3.5% indoors. In addition, the interior should also be equipped with glare control elements to reduce the discomfort of natural light [29]. Therefore, by allowing daylight to enter inside while improving visual performance, thermal and visual comfort will also be more efficient. The use of daylight in educational buildings brings major advantages in saving energy and reducing electrical energy consumption [30]. Some studies have shown a reduction in electric lighting consumption by 50% to 80% [31]. Using daylight control strategies can reduce glare in addition to increasing light distribution and uniformity [32]. In addition to reducing the glaring effects of light, the solar shade device can reduce solar gains, and thus prevent overheating. An efficient classroom design option includes an east-west axis plan with south-facing windows. The appropriate illumination level for offices, classrooms, and library space is 300 lx. Educational buildings require a minimum illumination level of 300 lx for classrooms and computer training, a minimum of 750 lx for technical design classes, and 500 lx for conference and meeting rooms [29]. Recent studies of light shelves have focused on configuration, surface reflectivity, and integration with other technologies, to improve daylight quality and optimize energy consumption (Table 1).

Table 1. Literature review.

Author (Year)	Light shelf variable	Primary results
Lim and Heng (2016) [33]	Height, reflector shape	Indoor illumination distribution
Meresi (2016) [34]	Width, angle, type	
Berardi and Anaraki (2016) [35]	Light shelf installation	Indoor illumination distribution, lighting energy consumption
Lee *et al*. (2017) [36]	Width, angle	
Warrier and Raphael (2017) [37]	Reflectance	Indoor illumination distribution, glare
Lee *et al*. (2018) [38]		
Kim *et al*. (2018) [39]	Angle	
Lee and Seo (2020) [40]		Indoor illumination distribution, electricity generation, lighting energy consumption
Mesloub and Ghosh (2020) [41]	Width, type, reflector type	
Lee (2020) [42]	Angle, reflectance	
Lee *et al*. (2021) [43]	Applying (PV) modules to light shelf reflectors	
Brzezicki, Marcin (2021) [44]		Improving uniformity and reducing glare
Ruggiero *et al*. (2021) [45]	Configurations of light shelves and clerestory window	Application of an internal horizontal light shelf placed at 50 cm from the top of the window with a depth of 90 or 60 cm.

Although recent studies have mainly focused on the effect of light shelf structuring on energy consumption and daylight quality, the simultaneous effects of window depth and the installation location of light shelves have been less investigated. The main objective of this work is to provide an efficient method to maximize building energy efficiency and minimize unhelpful daylight levels in educational spaces using light shelves. Therefore, the details of the installation of light shelves corresponding to the depth of the window have been checked, and the quality of internal light and energy efficiency has been calculated simultaneously, which is considered an innovative aspect of this research work.

2. Materials and Methods

Recently, designers have applied performance-driven generative design (PDGD) systems to achieve a higher environmental performance. Energy consumption intensity (EUI) is an index used to calculate the energy efficiency of a building. The value of EUI differs depending on the type of use of the building. For example, a hospital has a higher EUI than a small office building. Daylight is important both in terms of the energy required to illuminate a building and to improve the visually perceived quality of the indoor environment [46-52]. Although daylight is considered a vital factor for achieving visual comfort [53] and visual quality [54], at the same time, it can cause disturbances in the visual performance of the interior space [55]. If the glare is significantly higher than the luminance compatible with the human visual system, it can cause discomfort and poor visual performance [56]. Despite the limitations of the DGP model, such as not considering time effects, the DGP model is still considered the best indicator for visual comfort [57, 58]. In order to obtain suitable visual comfort in the studio, two variables need to measure:

- Illumination (E)
- Daylight Factor (DF)

Illuminance is the total illumination on a bright surface. It’s defined as the luminous flux.

- $E = \frac{F}{A}$
- E = Illuminance of a surface (lm/m^2 or lx)
- F = Luminous flux incident on the surface (lumen)
- A = The area of the surface (m^2)

Two useful variables in measuring appropriate visual comfort include illumination (E) and daylight factor (DF). The daylight factor (DF) is defined as the ratio of the daylight level in an indoor space to the outdoor light level in cloudy skies [59]. Daylight can reach the interior space through openings in three ways: direct light from a part of the visible sky (SC); Light reflected from external surfaces (ERC); light entering through windows and reflected from interior surfaces (IRC). The sum of the three components gives the illuminance level (typically measured in lux) at the point considered:

- Illuminance = SC + ERC + IRC

Designers use daylight factors (DF) to determine the adequacy of light for occupant activities. Daylight autonomy (DA), as a percentage of annual daylight hours, can be defined to save electric lighting energy. Usable daylight illuminance (UDI) is defined based on three illuminance ranges of 0-100 lux, 100-2000 lux, and more than 2000 lux. Among these ranges, only the range between 100 lux and 2000 lux is useful. 2000 lux is considered the "upper threshold"; if exceeded, it may cause problems such as glare or excessive heat. Also Daylight Saturation Percentage (DSP) defines the range of acceptable illumination between 430 and4300 lux. It is common to use simulation software to obtain building performance data [60]. In the process of searching for suitable design ideas, data analysis and computer simulation were considered, so that different options can be compared. Due to the reliability and accuracy of the results, a parametric method that coordinates climatic and site information in the project is considered [61, 62].

For the framework, various methods were used for the steps related to the generation of datasets, comparison of options, and validation of models. Rhino/Grasshopper was used to create the models and configurations of the canopy and light shelves. Ladybug and Honeybee plugins were used to model and evaluate visual comfort and calculate energy consumption. The DGP index was implemented in the radiance luminance calculation engine to represent the luminance of daylight sources. The roof and walls were considered without heat exchange (Adiabatic). The building is located in Abadan, Iran at latitude 30.37° and longitude 48.27°, which is generally hot and dry in summer. In this research work, it is used for thermal and lighting simulation (Figures 1, 2).

Then the chamber was designed to emulate a typical classroom, and had a large south-facing window. The class was 6.0 m wide by 8 m deep and 3.40 m tall to facilitate thermal measurements. The window was 2.1 m tall by 5 m wide. The window sill was 1.1 m above the level. Window sills are 1.1 m above floor level to allow for good visual contact with the outside [63]. In this study, two types of rooms with educational use have been evaluated to investigate the effect of a light shelf. Three cases of light shelves have been modeled for each type of classroom. A total of 6 rooms with light shelves and 2 rooms without light shelves are designed to simulate lighting and energy. Type A is considered as the initial state. In type B, the window is inserted 50 cm into the wall and the roof is used as a canopy.

The space created under the window will be used as a closet (Figure 3).

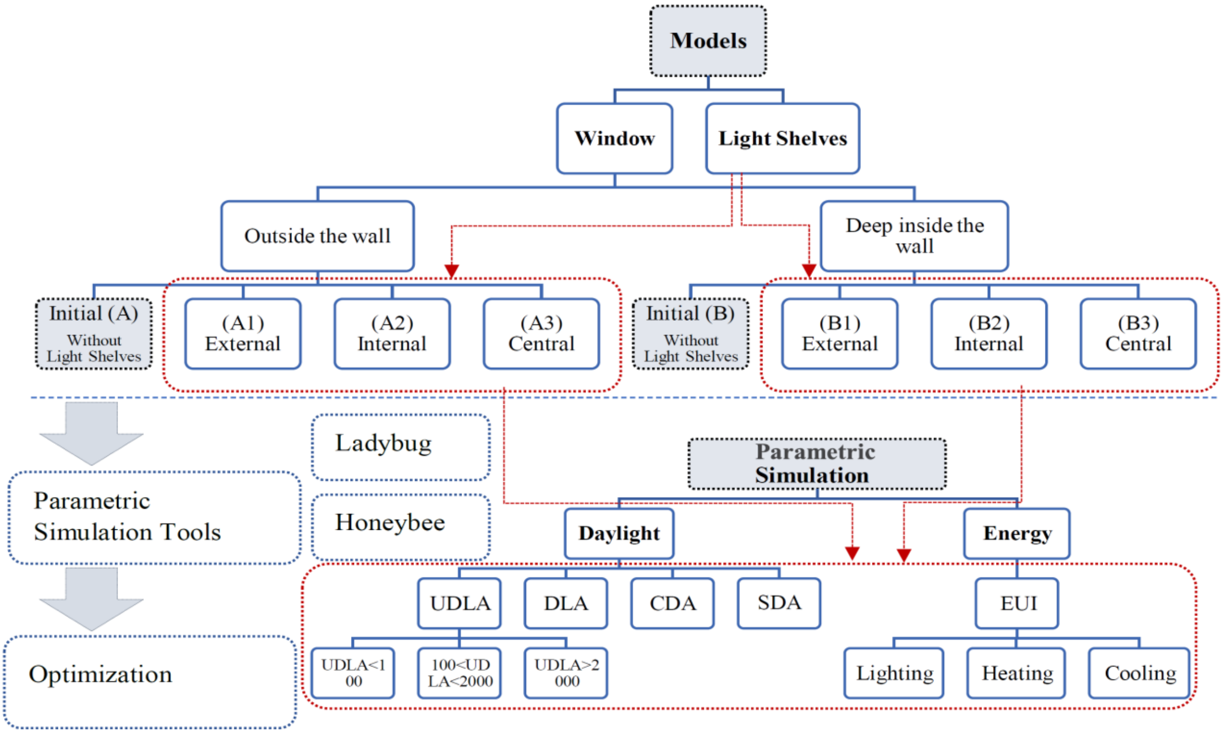

Figure 1. Research framework: daylight and energy optimization process and tools.

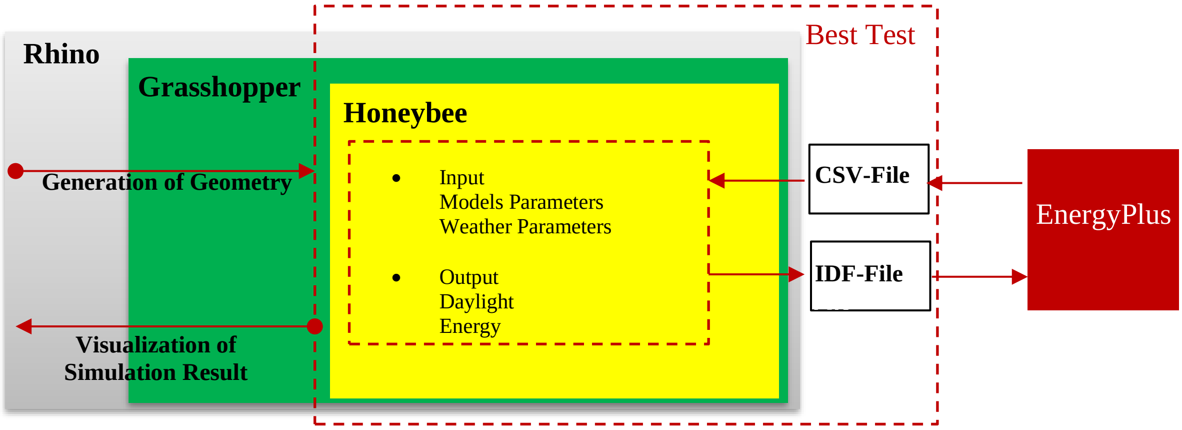

Figure 2. Data processing in Honeybee; validation performance can be identified at the blue dashed line border.

(A) The window is almost flush with the outer layer of the wall.

(B) The window is 50 cm deep inside the wall

Figure 3. Plan of the two initial models studied without the use of light shelf.

The 8 models of placement of light shelves in relation to the window are as follows (Figure 4):

- Model A: The initial case is without a light shelf. The window is almost flush with the outer layer of the wall.
  - Model A1: The light shelf is installed outside and is 1.3 m above the window sill.
  - Model A2: The light shelf is installed at the center of the depth of the wall and is 1.3 m above the window sill.
  - Model A3: The light shelf is installed inside and is 2.40 m above the floor level.
- Model B: It is similar to the initial case of A1 without a light shelf, while the window is 50 cm deep inside the wall:
  - Model B1: With the window 50 cm deep inside the wall, the light shelf is installed outside and is 1.3 m above the window sill.
  - Model B2: With the window 50 cm deep inside the wall, the light shelf is installed at the center of the depth of the wall and is 1.3 m above the window sill.
  - Model B3: With the window 50 cm deep inside the wall, the light shelf is installed inside and is 2.40 m above the floor level.

Figure 4. Different placement models for installing light shelves in the study.

To calculate the daylight brightness inside the classroom, we must have the reflection of the inside and outside surfaces (Table 2).

To calculate the thermal load of the building, the thermal characteristics of components are needed. (Table 3).

Table 2. Reflection coefficient of the surfaces.

Location	Type of surface	Reflection coefficient
Outdoor	The Earth outside	0.2
	Vertical shading surfaces	0.3
Indoor	Walls	0.5
	Roof	0.7
	Floor	0.2
	Furniture	0.5

Table 3. Thermal characteristics of the structural materials.

Elements	Components	Thermal resistance (m^2K/W)	Thermal conductivity coefficient (W/mK)	Diameter (m)
Window	Single pane glass	0.036	0.04	1.1
	PVC frame	0.086	0.25	2.9
Walls	Travertine	0.0125	0.03	2.4
	Cement coated	0.174	0.02	1.15
	Light grain concrete block	0.37	0.075	0.2
	Polystyrene insulation	0.31	0.05	0.16
	Light grain concrete block	0.37	0.075	0.2
	Plaster and soil coating	0.06	0.03	0.5
Roof	Mosaic	0.011	0.02	1.75
	Cement sand mortar	0.0174	0.02	1.15
	Waterproofing	0.086	0.02	0.23
	Rock wool	1.00	0.05	0.05
	Polypropylene vapor barrier	0.090	0.02	0.22
	Slope concrete	0.0285	0.05	1.75
	Structural roof	0.35	0.3	-

3. Results

Here the data from the simulation and the results are compared. The data includes the simulation results of the thermal and lighting performance of the models. For the analysis of DLA and UDLI maps, it should be noted: to measure the daylight metrics, the lux index is calculated at noon on July 1 at a height of 76 cm from the floor, which is the level of school desks. Thus gridding is done at this level and the average lux in each grid segment is calculated and displayed graphically. The optimal illumination is in the range of 300 lux and usually, the range between 0-2000 and above is specified in the legend of the diagram. The DLA index shows the percentage of times that each network receives light above 300 lux. For example, if DLA is 100 for a region, then the daylight metrics is always above 300 lux at that point. When UDLI is measured in the range of 100-2000, it indicates the percentage of the space that averages lux in this range. Therefore, when the diagram shows blue color in an area, it means that either the intensity of light in the area is less than 100 lux or above 2000 lux, which is not considered desirable. UDLI and DLA are considered annually. Areas that are colored red or orange in the simulated maps indicate optimal daylight metrics.

(A) Simulated results in models consider the window to be at the same level as the wall.

Model (A): In initial model (A), Energy consumption is 101.1 kWh/m^2, 90% of which is cooling. The DLA index indicates the daylight metrics above 300 lux throughout the year and in 25% of the area. Also, glare has occurred in the area near the window. The average illuminance at noon on July 1 is 950 lux. The UDLI index shows that 75% of the area has optimal conditions (Figure 5).

Model (A1): In model (A1), Energy consumption is 102.4 kWh/m^2, 90% of which is cooling. Here, the light shelf has increased energy consumption by 1%. The DLA index indicates the daylight metrics above 300 lux throughout the year and in 94% of the area. Also glare has occurred in the area near the window. The average illuminance at noon on July 1 is 1010 lux. The UDLI index shows that 82% of the area has optimal conditions (Figure 6).

Model (A2): In model (A2), energy consumption is 103.2 kWh/m^2, 90% of which is cooling. Here, the light shelf has increased energy consumption by 2%. The DLA index indicates the daylight metrics above 300 lux throughout the year and in 90% of the area. Glare in areas near the window is reduced by 51%. The average illuminance at noon on July 1 is 639 lux. The UDLI index shows that 88% of the area has optimal conditions (Figure 7).

Model (A3): In model (A3), energy consumption is 104.3 kWh/m^2, 90% of which is cooling. Here, the light shelf has increased energy consumption by 3%. The DLA index indicates the daylight metrics above 300 lux throughout the year and in 81% of the area. Also glare has occurred in the area near the window. The average illuminance at noon on July 1 is 520 lux. The UDLI index shows that 82% of the area has optimal conditions (Figure 8).

DLA % **100< UDLI <2000 %** **Illuminance**

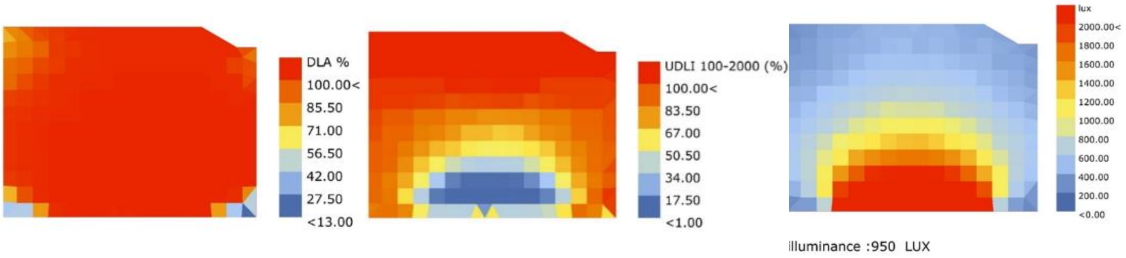

Figure 5. Simulated results in model (A).

DLA% **100 < UDLI < 2000%** **Illuminance**

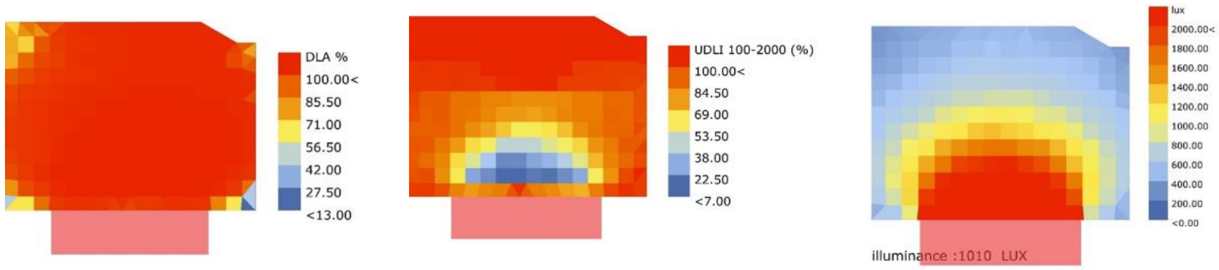

Figure 6. Simulated results in model (A1).

DLA % **100<UDLI<2000 %** **Illuminance**

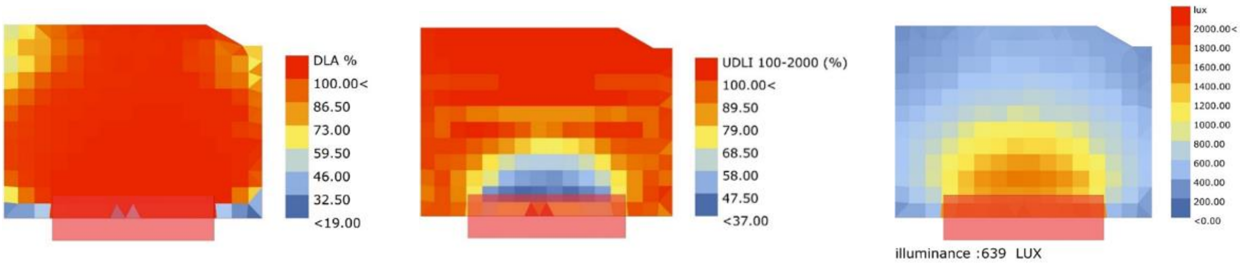

Figure 7. Simulated results in model (A2).

DLA % **100<UDLI<2000 %** **Illuminance**

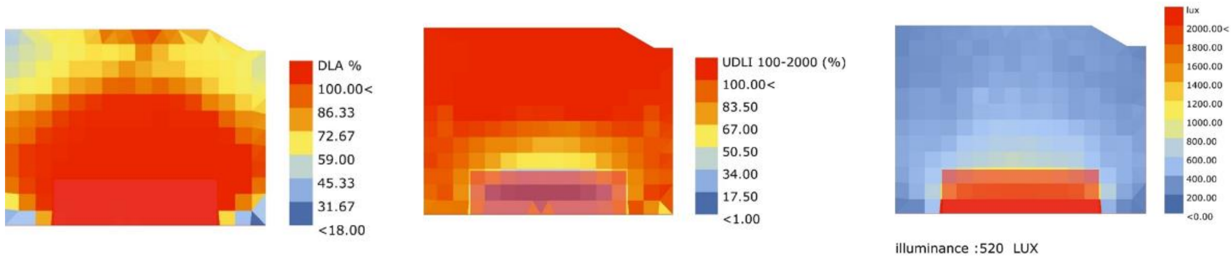

Figure 8. Simulated results in model (A3).

(B) Simulated results in models consider the deep windows

Model (B): In initial model (B), energy consumption is 87.8 kWh/m^2, 93% of which is cooling. This model shows a 13% reduction in energy consumption compared to the initial model (A). The DLA index indicates the daylight metrics above 300 lux throughout the year and in 92% of the area. Also glare has occurred in the area near the window. The average illuminance at noon on July 1 is 1016 lux. The UDLI index shows that 72% of the area has optimal conditions (Figure 9).

Model (B1): In model (B1), energy consumption is 79.4 kWh/m^2, 93% of which is cooling. Here, the light shelf has increased energy consumption by 21% compared to the initial model (A). The DLA index indicates the daylight metrics above 300 lux throughout the year and in 91% of the area. Glare in areas near the window is reduced by 30%. The average illuminance at noon on July 1 is 1087 lux.

The UDLI index shows that 82% of the area has optimal conditions (Figure 10).

Model (B2): In model (B2), energy consumption is 80.7 kWh/m^2, 93% of which is cooling. Here, the light shelf has increased energy consumption by 20% compared to the initial model (A). The DLA index indicates the daylight metrics above 300 lux throughout the year and in 87% of the area. Glare in areas near the window is reduced by 53%. The average illuminance at noon on July 1 is 643 lux. The UDLI index shows that 86% of the area has optimal conditions (Figure 11).

Model (B3): In model (B3), energy consumption is 86.6 kWh/m^2, 93% of which is cooling. Here, the light shelf has increased energy consumption by 20% compared to the initial model (A). The DLA index indicates the daylight metrics above 300 lux throughout the year and in 81% of the area. Also glare has occurred in the area near the window. The average illuminance at noon on July 1 is 520 lux. The UDLI index shows that 82% of the area has optimal conditions (Figure 12).

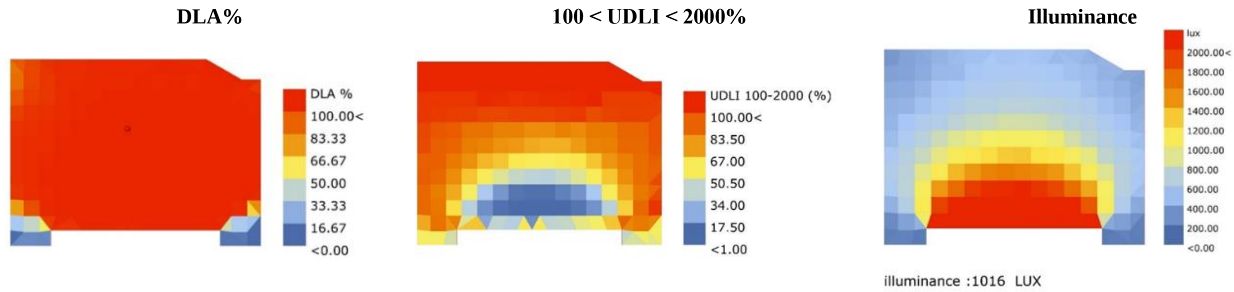

Figure 9. Simulated results in model (B).

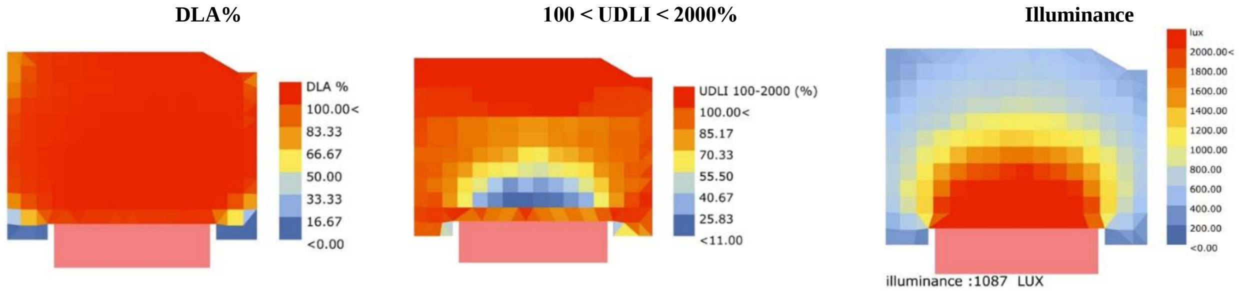

Figure 10. Simulated results in model (B1).

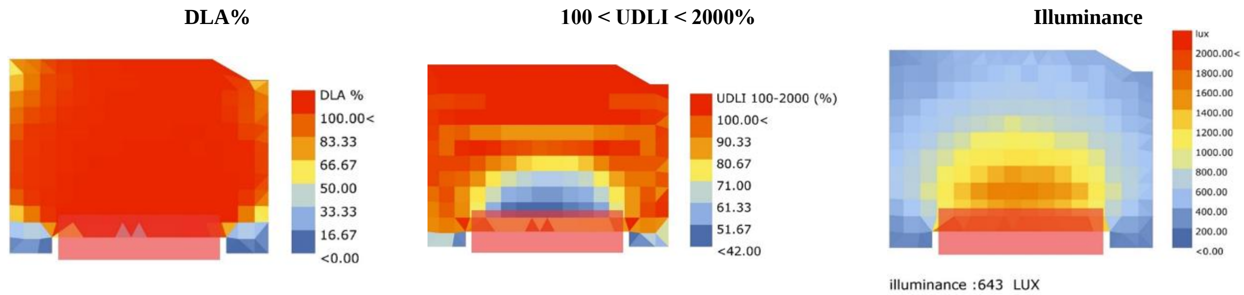

Figure 11. Simulated results in model (B2).

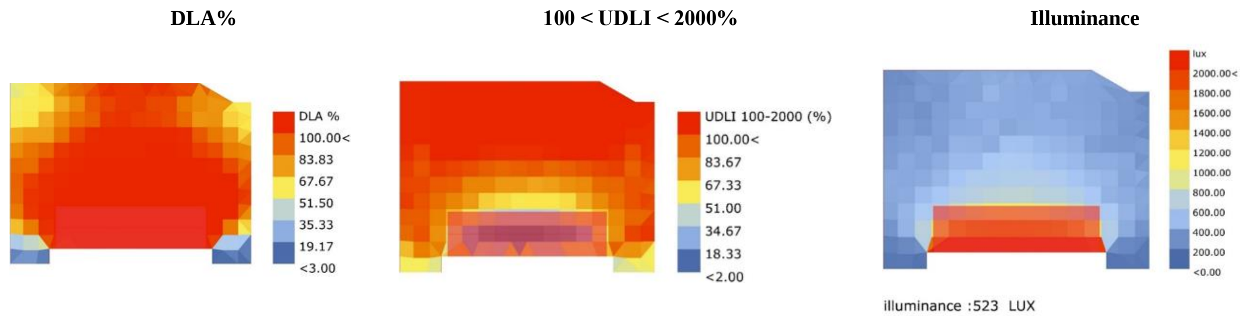

Figure 12. Simulated results in model (B3).

Table 4 provides all the energy and daylight metrics simulation data in models consider the window to be at the same level as the wall. According to the table, the internal light shelves provide the best conditions in terms of lighting. Also in the issue of energy consumption, the light shelves have not reduced energy consumption much.

Table 5 provides all the energy and daylight metrics simulation data models consider the window is inside the wall. According to the table, light shelves that are a combination of external and internal provide the best conditions in terms of glare control and lighting quality. Also light shelves have reduced energy consumption, especially, inside and combined light shelves had better energy performance.

Table 4. EUI and UDLI simulation data in models consider the window to be at the same level as the wall.

Type	DLA %	UDLI $_{<100}$ %	UDLI$_{100-2000}$ %	UDLI $_{>2000}$ %	SDA %	Lighting (kWh/m^2)	Heating (kWh/m^2)	Cooling (kWh/m^2)	EUI (kWh/m^2)
A	95.74	0.50	75.54	23.91	97.69	3.60	7.26	90.24	101.10
A1	94.86	0.18	82.35	17.39	98.61	3.68	6.96	91.79	102.42
A2	90.57	0.33	87.89	11.72	95.83	3.70	7.03	92.51	103.24
A3	81.41	0.64	82.62	16.69	94.91	3.69	7.03	93.59	104.31

Table 5. EUI and UDLI simulation data in models consider deep windows.

Type	DLA %	UDLI $_{<100}$ %	UDLI$_{100-2000}$ %	UDLI $_{>2000}$ %	SDA %	Lighting (kWh/m^2)	Heating (kWh/m^2)	Cooling (kWh/m^2)	EUI (kWh/m^2)
B	92.24	3.14	72.74	24.09	92.89	3.59	2.67	81.58	87.84
B1	91.11	1.76	81.64	16.51	94.76	3.59	3.65	72.15	79.39
B2	87.54	2.58	86.20	11.15	91.00	3.59	3.00	74.16	80.74
B3	82.87	3.20	79.97	16.77	91.47	3.59	2.34	80.70	86.63

4. Discussion

This section includes a discussion of energy and lighting results by a comparison. Energy consumption in model (B) was lower than in model (A). Therefore, considering the window in the depth of the wall, improved the energy efficiency of the building. In model B, light shelves significantly reduced EUI. Among all the models, in type B1, the external light shelf caused the lowest EUI (Figure 13).

By comparing all the results, we can conclude if SDA is above 55, the conditions will be favorable. This condition existed in all the rooms. The illumination was adequate even in the initial model, and then the main problem was reducing excessive light and glare. The illumination in the cases with inside light shelves was the lowest, while the external light shelves had the best performance. In models A and B, light shelves reduced glare. Among all models, the central light shelves reduced UDLI the most.

In model B, the deep window has reduced energy consumption (13%), and using light shelves has improved energy performance (14% to 20%). Compared to the base model (A), the combined light shelves reduced UDI by 20% and glare by 53%, while the inside light shelves reduced UDI by 14% and glare by 30%. Compared to the combined light shelves, although the outside light shelves had better energy performance, the combined light shelves had a much better performance in glare control (Table 6).

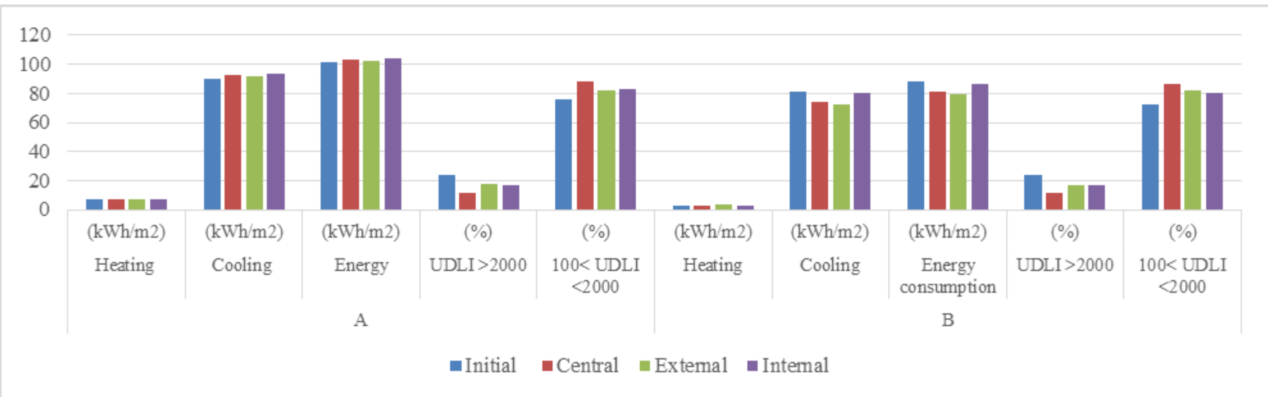

Figure 13. Energy consumption comparison chart.

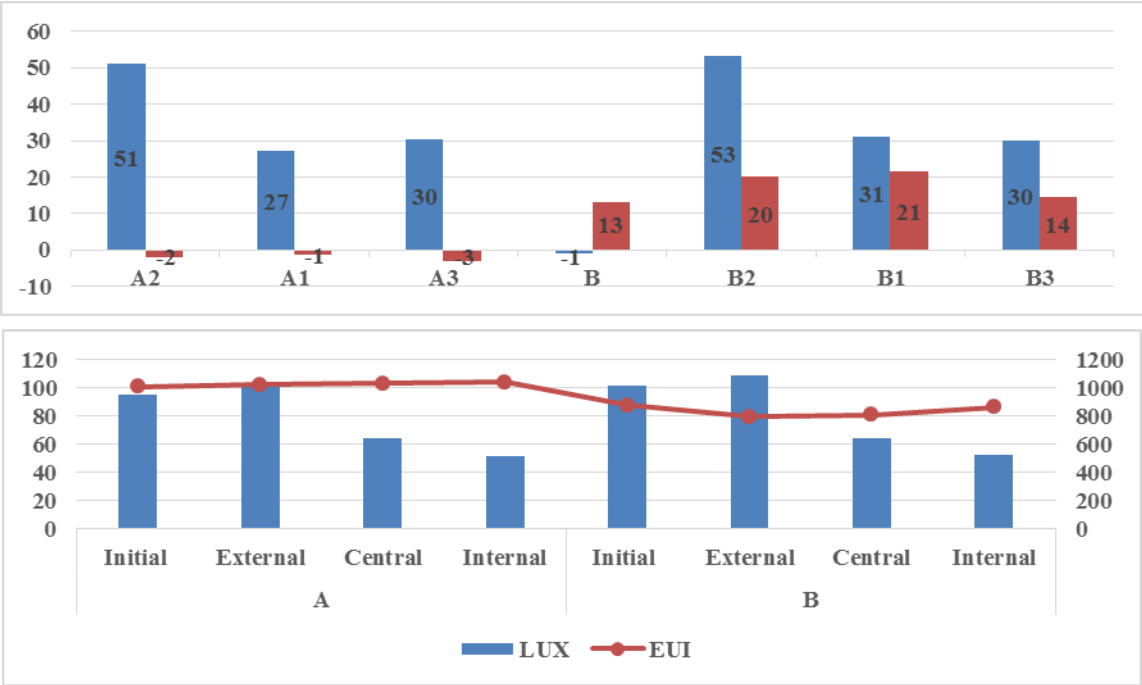

Figure 14. Comparison chart of models in glare reduction and EUI.

Table 6. Energy and daylight metrics simulation data in models consider the window to be at the same level as the wall.

Type	UDLI < 100 %	100 < UDLI < 2000 %	UDLI > 2000 %	Comparative glare	Heating (kWh/m^2)	Cooling (kWh/m^2)	Lighting (kWh/m^2)	EUI (kWh/m^2)	Comparative EUI (kWh/m^2)
A	0.50	75.54	23.91	-	7.26	90.24	3.60	101.10	
A1	0.18	82.35	17.39	27.27	6.96	91.79	3.68	102.42	-1
A2	0.33	87.89	11.72	50.98	7.03	92.51	3.70	103.24	-2
A3	0.64	82.62	16.69	30.20	7.03	93.59	3.69	104.31	-3
B	3.14	72.74	24.09	0.00	2.67	81.58	3.59	87.84	13
B1	1.76	81.64	16.51	30.95	3.65	72.15	3.59	79.39	21
B2	2.58	86.20	11.15	53.37	3.00	74.16	3.59	80.74	20
B3	3.20	79.97	16.77	29.86	2.34	80.70	3.59	86.63	14

5. Conclusions

By comparing the types of external, internal, and central shelves and in different situations of window depth, the following results were obtained:
(1) By installing the window in the depth of the wall: energy consumption decreased by 13%; and there was no significant effect in reducing glare.
(2) The effects of installing light shelves in windows flush with the wall:

- In external light shelves: energy consumption increased by 1%, and glare effects were reduced by 27.27%.
- In central light shelves: energy consumption increased by 2%, and glare effects were reduced by 50.98%.
- In internal light shelves: energy consumption increased by 3%, and glare effects were reduced by 30.20%.

(3) The effects of installing light shelves and deep windows where used together:

- In external light shelves: energy consumption decreased by 21%, and glare effects were reduced by 30.95%.
- In central light shelves: energy consumption decreased by 20%, and glare effects were reduced by 53.37%.
- In internal light shelves: energy consumption decreased by 14%, and glare effects were reduced by 29.86%.

As a result, in the case of a window flush with the wall, light shelves hurt energy efficiency due to the cooling in hot hours and the use of artificial lighting to compensate for the illumination. In this case, the light shelves, especially the central shelf, reduce glare. Installing a window in the depth of the wall doesn't have much effect on reducing energy consumption but to some extent, it controls the intensity of glare. The combined use of deep windows and light shelves reduces EUI, especially in the case of external and central shelves. In this case, the internal shelf doesn't increase energy efficiency but reduces glare, especially the central light shelves are effective in reducing glare. Therefore, the central light shelves, in both positions of the window, have an effective efficiency in the glare. If the intention is energy efficiency, the central and external light shelves are very useful in the deep window position.

6. Nomenclature

DA	Daylight autonomy
DF	Daylight Factor
DGI	Daylight Glare Index
DSP	Daylight Saturation Percentage
ERC	Externally Reflected Component
EUI	Energy Usage Intensity
IRC	Internally Reflected Component
PDGD	Performance Driven Generative Design
SC	Sky Component
SDA	Spatial Daylight Autonomy
UI	Uniformity index
UDI	Useful daylight illuminance
$UDLI_{100–2000}$	Useful Daylight Illuminance with the Range of 100–2000 lx
WWR	Window-to-Wall Ratio

7. References

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