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Original Research Article

Enhancement of the Potential of Exterior Louvre Shadings for Internal Daylight Distribution and Space Visual Quality in Isfahan City, Iran

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Abstract

Problem statement: The importance of visual comfort in buildings lies in its profound impact on the well-being and productivity of occupants. This architectural aspect would be more noticeable in educational space which can be achieved through utilizing appropriate daylight strategies. Shading elements can be utilized to enhance visual quality and optimize daylight distribution, leading to a more pleasant and productive environment for occupants.

Research objective: This research focuses on examining the physical properties of slats for external horizontal louvres for four façade orientations of an educational case study with a north-south direction in Esfahan City, Iran to enhance the daylight and space visual comfort performance.

Research method: The daylight factor and visual quality metrics, namely the Maximum radial line and the Isovist area are investigated as research objectives. Also, the reflection coefficient of materials louvre slats, the depth of slats, and the distance between them are considered independent variables. The literature studies were scrutinized and field measurements by Lux Meter, climate analysis by Climate Consultant 5. 4 software as well and computer simulations via Relux and Isovist tool on depth map software were utilized to investigate the set research objectives.

Conclusion: The results indicate that advising a specific design of louvre shading parameters for each façade orientation is recommended for a particular climate. Additionally, materials with an 80 percent reflectivity coefficient are deemed suitable to achieve a balance between daylight factor distribution and visual quality metrics for building occupants.

Keywords: *Educational Space, Daylight Factor, Visual Quality, Shading Element, Relux Lighting Software, Isovist Tool.*

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Introduction

Qualitative environmental factors have always engaged designers, architects, and researchers to achieve human comfort. Besides, the preservation of balance in the environment leads to global consistency, the sustainability of humans' survival, and the environment they live in. Hence, the application of natural sunlight and solar heat, considering proper solutions during the day and night, can considerably help maintain a balance in the human environment (Doulos et al., 2008; Kurian et al., 2008; Loutzenhiser et al., 2007). In this way, glass facades and shading equipment play an important role in daylight distribution and visual comfort in buildings. To put this in perspective, one effective way to reduce daylight and visual discomfort is to prevent direct sunlight from reaching the glass sections of the building. These glass sections can especially affect the visual and daylight conditions of the space. In this way, the use of canopy equipment, especially horizontal and louvre-shaped shadings, improves the interior conditions of buildings in various ways (Radhi et al., 2009). As a matter of fact, building skins, especially facades, are in direct contact with the outdoor environment, and natural elements. The facade acts not only as a neutral skin responsible for indoor and outdoor segregation but can also go beyond and turn into an active component that causes an interaction between the indoor and the outdoor environment of the building (Ding et al., 2014).

The inappropriate orientation of windows and inadequate shading may cause glare and excessive heat problems, even if it is a sunny winter day. There are also similar and additional problems with daylight and visual comfort from spring to fall, especially in hot and dry climates. For instance, unsuitable lighting conditions due to the uneven distribution of daylight result in glare and inadequate illumination at the end of space (Tsikra & Andreou, 2017). In this regard, studies on the use of natural light and the better vision of users have received much attention in recent years (Chi, 2022; Hien et al., 2005; Iommi, 2019; Khidmat, Fukuda, Paramita, Qingsong, et al., 2022; Poirazis et al., 2008; Samiou et al., 2022). Some studies show the effect of different types of external shadings is about 80% in reducing the amount of solar heat storage. According to these studies, the air must move easily in the structure of all external shadings, especially horizontal louvres, to remove the absorbed heat from the shadings away from the glass part of the building (Suziyana et al., 2013). In another study on shading devices for buildings, a broad range of shading strategies is addressed for transparent facades (Kirimtat et al., 2016). In a study, Al-Tamimi and Fadzil assessed the effect of sunshades on the reduction of temperatures in high-rise buildings. Exterior shading devices such as egg crates, louvres, and protruded edges protect the building walls and residents from heat absorption and high indoor daylight. Shading devices improve thermal comfort conditions in both ventilated and non-ventilated rooms. According to the evaluations in this study, the egg-crate is the best device for reducing indoor temperature and thermal discomfort hours due to sunlight protection at different angles, which improves thermal comfort conditions by 26% for non-ventilated space and 4% for ventilated space (Al-Tamimi & Fadzil, 2011). In a study, Nikpour et al. conducted an experimental investigation on the quality of daylight using the self-shading strategy. Evaluating the quality of daylight based on various criteria such as work plane lighting, daylight factor (DF), surface illumination, and comparison with recommended values in this study shows that the number of hours of internal daylight decreases (Nikpour et al., 2013). In addition, Alhuwayil et al. found that exterior sunshades significantly improve visual comfort and reduce glare in classrooms (Alhuwayil et al., 2019).

Additional studies in this area emphasize the significance of this inquiry. For instance, one study (Lakhdari et al., 2021) attempted to enhance thermal and visual comfort by optimizing the louvres. The distance between the louvre, and the depth of the louvre were all taken into account in this study. The findings demonstrated that each of these factors has a beneficial and efficient impact on thermal, optical, and daylight comfort in buildings. A different study (Palarino & Piderit, 2020) attempted to maximize daylight penetration and minimize glare danger by using passive solar design solutions. The study was conducted in Chile, which has a different temperature, and it makes use of shading devices like light shelves with various details and external louvres. According to this study, using shade devices in each environment should be specific and optimized.

Furthermore, another study looked into the effects of louvre form, the spacing between its slats, and the angle at which it should be positioned (Triantafyllidou & Michael, 2020). The effect of adding a concave, curved profile blind to a glass window for visual comfort was examined in this study (ibid.). Through optimization and analysis of these factors for daylight performance in buildings, this research has led to a significant shift in each of these parameters for both daylight and visual comfort in a particular climate (ibid.). In one study, the use of horizontal louvres was examined as a way to balance the availability of daylight and visual comfort (ElBatran & Ismaeel, 2021). For the louvres on the south, west, and east building façade orientations, a parametric design technique was used in this study, taking into account the size, depth, and distance from the outer wall (ibid.). The impact of louvre form on daylight and visual comfort in Egypt's New Cairo was also examined in one study (Eltaweel et al., 2021). The study discovered that, when designed appropriately for each environment, material reflectivity, slat spacing, and size all have a favorable impact on how daylight is distributed (ibid.). Furthermore, the researcher optimized louvre shading devices in three distinct temperature zones—Bristol, UK; Jakarta, Indonesia; and Sydney, Australia—to determine the optimal louvre design configuration for each particular situation (Khidmat, Fukuda, Paramita, & Koerniawan, 2022). In Tehran, Iran, researchers looked into how four different orientations of louvres—angle, depth, number of slats, and distance to walls—affect daylight performance and visual comfort (Changlani, 2020).

In a single study, the localization of the louvre configuration for each climate was examined for three Canadian cities: Vancouver, Montreal, and Edmonton (Rafati et al., 2023). The purpose of this study was to demonstrate the necessity of various louvre types, even in locations with the same climate zone. Thus, research on the Louvre design is being done in three cities with climates that are very similar. In this study, energy usage and daylight intensity are the objective functions. The findings demonstrated that louvre installation always improves energy efficiency and visual comfort. Furthermore, because of the city's altitude, the depth of the Louvre, its distance from the wall, and the number of louvres is all significant elements that affect different things (De Luca et al., 2022). Also, Shaeri et al. evaluated the effect of louvre shading devices on energy consumption for the south, east, and west facades of a building. This research determined the optimum lover angle for a hot, semi-arid, warm steppe, and cold, semi-arid climate. The results indicated that using louvre shading devices reduces solar heat gain, especially in Bushehr and Shiraz, which have hot semi-arid and warm steppe climates (Shaeri et al., 2022).

Other studies looked into the parameters of the louvres in two classrooms in Tallinn, Estonia's northern metropolis, for glare, lighting, view, and energy considerations. The results demonstrated that static shadings reduced visual discomfort by as much as 89.8% for the kind of building and location, while also reducing primary energy use by as much as 29.1% and offering sufficient daylight and outside views. Detailed data and the shading types that perform best are shown and discussed (Wang et al., 2022). Additionally, researchers looked into the composite external louvre shading in one classroom's east, west, south, and north orientations based on daylight and visual comfort. Their findings indicated that lighting quality and visual comfort are enhanced when the established classroom model's east, west, south, and north orientations have the ideal dimensions for vertical and horizontal shading. The suggested design approach for the classroom's external shading system can significantly improve indoor lighting quality and visual comfort while also lowering the overall annual energy use intensity (Task, 2000). Konis and Eleanor assessed the Louvre system under real sun and sky conditions, and their results clarified that this system, compared with conventional blinds, considerably reduces the annual electrical lighting energy demand and improves the lighting quality by removing window glare (Konis & Lee, 2015).

To explain the Isovist tool, it should be said that this tool provides a regular geometric grid for the building's space (Christenson, 2010; Wiener & Franz, 2004). Also, Benedict and Burnham showed the effect of Isovist components on the perception of space and proved that the perception of "spatiality" is related to the complexity of spatial visual contexts (Benedikt & Burnham, 1985). In this regard, Tahir and Brown investigated the traditional houses of Mumbai and asserted that the visual background of the houses is in line with the privacy needs of the residents (Brown, 2003). Also, Franz and Weiner sought the connection between the experimental qualities of space and their visual (Isovist) contexts. Moreover, they indicated that there is a significant relationship between spatial properties and perceptual responses to space (Franz et al., 2005). In what follows, Dawes et al. examine the landscape shelter theory by the Isovist tool in Frank Lloyd Wright's textile-block houses (Ostwald & Dawes, 2013). Furthermore, Dezbek showed that the perceptual responses of the participants in the virtual experiments were significantly correlated with the Isovist area indexes (Dzebic, 2013). Dawes et al and Lee et al examined Palladio's villa plans using space syntax to measure visual quality in this space (Dawes et al., 2021; Lee & Ostwald, 2020). Moreover, in other research, the relationship between the Isovist index and the daylight factor was investigated and its positive relationship was approved (Esfandiari & Shokry, 2023; Xiang et al., 2021). Due to the overlap of indexes in this study, the two indexes, namely the maximum radial line (Rl(l)) and Isovist area, have been selected. In this research, three shadings (vertical fins, diagonal fins, and egg crate) were simulated and experimentally evaluated on two different floors, so that air temperature, illumination level, ambient temperature, and comfort were monitored and compared to the no shading conditions (Freewan, 2014).

Exterior sunshades can be useful and influential in creating a good optical, visual, and thermal environment for users as a passive building system. Shadings are used to control the amount of sunlight passing through transparent surfaces in buildings. Due to Iran's national requirements office, since Iran is located in the northern hemisphere, horizontal shadings can reduce solar heat storage in southern, eastern, southeastern, and southwestern facades during spring, summer, and early fall, depending on the angle of the sun's rays. The angle of the sun's rays on the northern and western facades is generally minimal throughout the year, so horizontal shadings do not have much effect on reducing sun radiation. Therefore, in this case, vertical shadings are used for east and west facades to control direct sunlight. Because the building can have different directions, and there is a direction in each climate. In this study, the effect of using horizontal and vertical louvre shadings on the southern, northern, eastern, and western facades of the educational building has been investigated in the arid climate of Isfahan. Field studies and measurements have been used by the lux meter as well as the Relux simulation software and the Isovist tool in the review process. Fig. 1 also displays the growth and quantity of studies in the

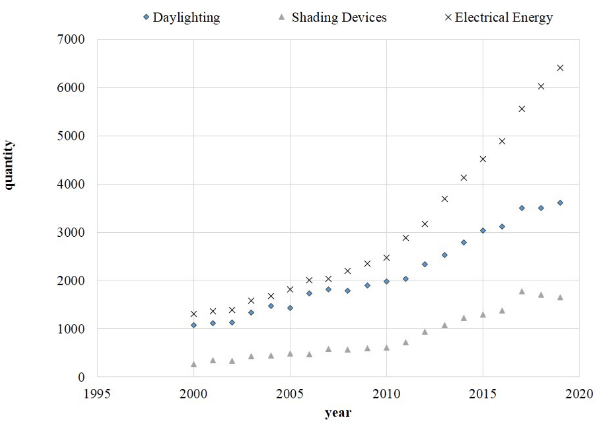


Fig. 1. The trend of studies in three research areas in recent years. Source: Authors.

These subjects have been the most important issues noticed in recent years, and the discussion and study on these subjects can be so influential for the growth and development of the community of researchers, engineers, and especially architects. Therefore, this study evaluates the physical characteristics of external horizontal and vertical louvres in the eastern, northern, western, and southern fronts of the building with educational usage for the hot and dry climate of Isfahan. Independent research variables include depth and distance between louvres, reflection coefficient (RHO) of blades, and dependent variables also include daylight factor (DF), and visual comfort indexes, namely the maximum radial line (Rl (l)) and Isovist area. This study can play a vital role in achieving a green and sustainable architecture, helping reduce energy consumption, fossil fuels, pollution, and global warming. Therefore, it helps create a good architectural environment for users and somewhat eliminates the research gap in this regard.

On the other hand, the IEA handbook (Kirimtat et al., 2016), states that the efficacy of external louvres is dependent on latitude and climate. This dependence highlights how crucial it is to take context and local demands into account when constructing louvres (Villalba et al., 2005). Furthermore, provincial building codes do not specify contextual louvre design in great detail. Because of this, a lot of louvre systems are marketed without a clear context or climate adaptation for their performance (Bhavani & Khan, 2011), which leads to insufficient application and negative consequences for building energy efficiency and visual comfort. In actuality, some nations lack any regulations to help builders and designers create shade devices. They don't provide exact methods to achieve these objectives; they just supply the basic visual and thermal criteria. Based on the reviewed different louvres parameters, it could be concluded that none of the research tried to assess all the influencing parameters; however, they merely examined a limited number of parameters due to the complexity of the optimization process. Moreover, based on this recent state-of-the-art research, it is found that external horizontal and vertical louvres still need more investigations due to the climate effect and façade orientations.

As a matter of fact, external louvres are affected by climate and façade orientation which requires them to be localized for each specific climate and orientation. The need for a localized exterior louvre is more noticeable in hot and dry climates such as the one in Isfahan, Iran in this case given not enough academic research in this area. This could improve the daylight and energy efficiency potential of external louvres, leading to more sustainable and green buildings. Moreover, most of the studies in this field of knowledge are carried out with some experimental and simulation-based methodology through some software among which RELUX is a new daylight tool. Due to a raytracing method, a big material library, and also the ability to consider furniture and internal partitions in an architectural plan for RELUX. In addition, it was not seen any research to consider the visual quality metrics with the Isovist tool in line with RELUX daylight metrics. All these together make the current research worth investigating this issue to fill the scientific gap in this area and advance beyond previous studies. This research is going to propose optimum external louvre shading for each specific façade orientation in Isfahan, the hot and dry climate of Iran. Moreover, the research aims to enhance the ability of external horizontal and vertical louvre shadings on daylight performance and space visual quality by optimizing their parameters. And also, to answer these questions; what optimum parameters of external louvre shading assure better performance of the shading in daylight and visual quality in one specific climate? What are the exact amount of louvre shading parameters which have best performance for different orientation of educational buildings in Esfahan, Iran? How can louvres parameters affect the daylight performance and visual quality index?

Research Method

To investigate the research objectives, first, a literature survey in the field of the theoretical research foundations and the research background has been done. For the analysis of climatic conditions and the proposed model's simulation of horizontal and vertical external louvre shadings for the southern, northern, eastern, and western facades of the base model, as well as daylight distribution, the computer simulation method through Relux software is used. This study has considered the hot and dry climate of Isfahan city to study the effect of daylight through the implementation of louvre shadings. Due to the positive effect of daylight on visual comfort, and productivity in educational spaces and classrooms, an educational case study is considered for daylight and visual quality analyses. Moreover, the maximum of radial lines and Isovist area indexes are checked by the Isovist tool through DepthMap software. Fig. 2 shows a diagram of the research process.

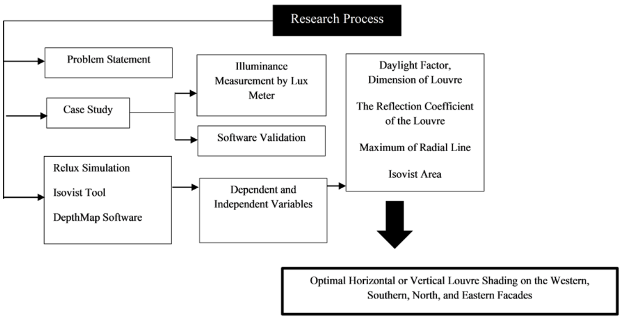


Fig. 2. The current research framework. Source: Authors.

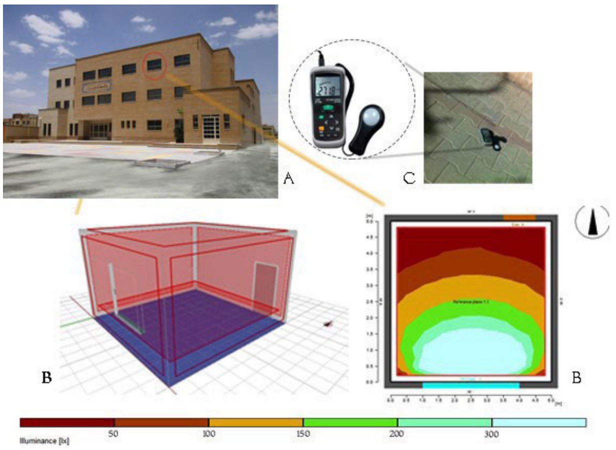


Fig .3. a) Southern façade of the educational case study, b) Geometry of the validation and simulation model, c) Lux meter used in field measurement. Source: Authors.

- **Validation**

Numerous studies demonstrate that the simulated results should be compared to the measured data (Haberl & Bou-Saada, 1998). This approach is usually known as simulation model validation (Sreshthaputra et al., 2004). Here, the simulation validation is done based on measured illumination in a real sample. As shown in Fig .3, a small classroom is given as the area of field measurement, and data validation, and the basic model in the simulations in an educational building in the city of Isfahan is considered. In this regard, the illumination of 20 points inside the room is measured by a Lux meter (Fig .3), and after recording the data, experimental and simulation data are compared. Given the analyses via statistical programs such as Excel and SPSS, the results suggest that the simulation process is reliable and the research results can be trusted. In addition, Table 1 shows the connection between Isovist indicators in the field of spatial experience according to previous studies as a validation.

Table 2 provides a list of lighting simulation programs along with an overview of their features and advantages. While some software is solely focused on lighting, others integrate lighting with other building-related computations. Due to research variables and not much study through RELUX software, it could be a good new tool for daylight analyses. Also, the profusion of research methods employed in diverse and valid articles related to the subject of this research has demonstrated that the field measurement method has been the most used, and after that, the usage of radiance software has been the most used. The third place goes to using Relax software. This can be attributable to the suitable capabilities and responsiveness of these research instruments.

Results

Some factors should be considered to study the effect of shadings in the desired climate. First, according to the warm times of the year in the desired area, the sun radiation angle must be obtained to identify the need for shading in different façade orientations. Accordingly,

Table 1. The visual quality indicators along with spatial experience. Source: Franz et al., 2005; Meilinger et al., 2012; Ostwald & Dawes, 2013.

Indicator	Definition	Spatial experience (visually)
Maximum radial line (Rl(l))	The length of the longest radius which can be seen from the observer point	Landscape
Isovist area (A)	The number of points that can be seen from the observer point	Landscape/space and space opening

Table 2. Some lighting simulation software. Source: Kirimtat et al., 2016.

Name of software	Light process	Features
Radiance	Ray tracing	Global illumination using the Monte Carlo method
Relux	RADIANCE engine supplemented with Radiosity Method	Inbuilt with ReluxCAD, energy calculation by EN15193 and DIN8599 standards
ADELINE	Radiosity	ADELINE contains SCRIBE.MODELLER as CAD interface, the lighting tools SUPERLITE and RADIANCE
DIALux	Integrated Ray tracing	Emergency lighting according to EN1838, Energy evaluation according to DINV 18599 and EN15899
Lightscape	Radiosity	Made by Autodesk, possible to change viewpoints without recalculating the scene
DAYSIM	Ray tracing	Precise sky modeling taking into account the sun's position and real sky distribution

the whole surface of the window enjoys shade at the mentioned times and prevents sunlight from entering and creating unfavorable thermal and visual conditions. Initially, the position of the sun should be checked according to the latitude to determine the need for shade. As a result, the time required for the canopy is determined by the hot days of the year. The height angle of the sun's rays with the position of the sun is relative to the building facade at the desired time, which shows the location of the sun. In this regard, the angle of the sun's height and the need for canopy in different months and hours of the day and year are obtained from Equations 1 to 4 and Table 3. In 1 & 2 equations, "a" is the altitude solar angle, and "q" is the azimuth angle.

In 3 & 4 equations, d is the angle of sun deviation, and w sun hour angle calculated by 2 & 3 equations (Bakirci, 2012).

$$\text{Sin a} = \cos\int * \cos d * \cos w + \sin\int * \sin d \quad \text{Eq. 1}$$

$$\text{Sin q} = (\cos d * \cos w) / \cos a \quad \text{Eq. 2}$$

$$d=23.46 \sin (360\, n /365) \quad \text{Eq. 3}$$

$$W = 15(t\text{-}12) \quad \text{Eq. 4}$$

In 3& 4 equations, n is the number of days (based on the Iranian calendar), and t is time based on the hour. The absorber surface absorbs the maximum amount of radiation when the solar radiation is vertical on it (Benghanem, 2011). According to Tables 4 & 5, the angle of solar radiation in the comfort state is between 40 and 50°. Therefore, t shows shading when this angle is out of the desired range and more than 50°. Therefore, this period of day and night is considered for the desired months in the simulations. According to Table 4, the need for a canopy in yellow is specified for different months of the year. As it turns out, from March 21 to September 21, a lot of shading is needed. The angle of the sun's height at different times is also given during these hot months of the year. The 21st day of each month from March to September at 11 a.m. is examined in terms of canopy and daylight factors to prevent recurrence and prolong research. Due to simulation time and the software type, the investigation is carried out in one month (June) which is a high amount of necessity for a shading device in the 21st. In fact, when the shading device e optimized for the worst conditions it acts properly in other conditions and seasons and the average amount of variables is represented for one month (21st June).

On the other hand, Table 6 shows the type and suitable angle of the canopy for windows in various directions for the latitude of 32 degrees for the city of Isfahan according to the National Building Regulations of Iran.

Table 3. Climate Details and Monthly Average Climate Variables at Isfahan Station (1951-2010). Source: Meteorological Organization of Iran

City	Climate	Solar Altitude Angle of comfort months	Solar Altitude Angle of hot months	The temperature of the warmest month		A hot and dry period of the year		Wet period of the year		Hottest month	latitude	Need of shading
Isfahan	Hot and dry	40-50 degree	50-80 degree	The average temperature is 27.4 degrees Celsius		March 21 to October 21		October 21 to March 21		August	32 degrees and 38 minutes and 30 seconds north	*
Month	December	November	October	September	August	July	June	May	April	March	February	January
Average air temperature (degrees Celsius)	5	10.1	17	23.3	27.4	29	26.6	21.1	16	10.7	6.2	3.4
The average hours of sunshine	6.33	7.46	9.07	10.42	11	11.27	11.63	9.95	8.36	8.21	7.74	6.6

Table 4 . Results for solar altitude at different hours and months of the year (Climate Consultant Software). Source:Authors.

	Solar altitude										
Month	7 am	8 am	9 am	10 am	11 am	12 noon	1 pm	2 pm	3 pm	4 pm	5 pm
March	15	25	37	47	55	57	55	47	37	25	15
April	18	32	43	55	65	70	65	55	43	32	18
May	23	37	48	60	72	78	72	60	48	37	23
June	25	38	50	62	74	80	74	62	50	38	25
July	23	35	48	60	72	78	72	60	48	35	23
Aguste	19	31	43	55	65	69	65	55	43	31	19
September	13	25	38	48	55	58	55	48	38	25	13

Table 5. Type and angle of optimal shading on different facades of the building. Source: the National Building Regulations of Iran.

	West face	East face	North face	South face
louvre Types	vertical	horizontal	vertical	horizontal
Angle α (in the vertical canopy) β (in the horizontal canopy)	In front of the whole window	β = 45	α = 70 in the west window	β =60

Also, due to this standard, the depth of the optimal shading for this climate is shown in Fig. 4.

First, the effect of the dimensions and distance between the louvres and the effect of the blade material refraction for the optimal state of the louvre's dimensions are examined through Table 6 matrix. The examination is done on the south, east, north, and west facades obtained in the previous step to investigate the effect of shadings in terms of daylight distribution and the changes in research variables. In this way, 36 scenarios have been studied for reaching the optimal dimensions and distance for louvre-shaped shaders on each facade in terms of daylight distribution. In the next step, the necessary studies have been done in terms of the appropriate reflection coefficient of the blades. The louvre used at this stage of the research is a fixed horizontal and vertical aluminum spindle with a 6063-alloy shape with a reflection coefficient of 62%, and an angle of 5.22° for the blades. This type of louvre has the highest resistance to winds of more than 150km.h^{-1} and adverse conditions, which do not need to be maintained after installation. The only difference is that the shaders on the various

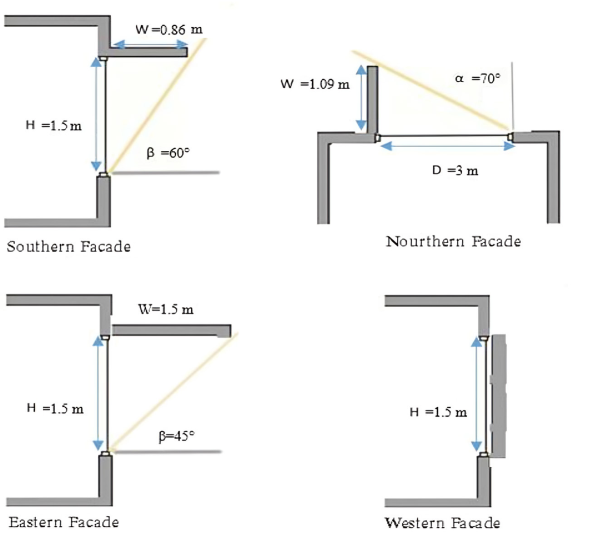


Fig. 4. Property of the initial simulated model on different facades. Source: Authors.

facades around it are empty and without side spaces. Investigations for the dimensions and distance between the louvres are also performed according to the specifications obtained from the manufacturer. Moreover, the amount of reflectivity is within the range of common materials used in the manufacture of louvres such as wood, metal, and aluminum.

Discussions

• Daylight analysis

The daylight factor (DF) in each scenario has been considered for examining daylight distribution for the depth of the shading with the different dimensions. In this way, the initial canopy state, according to Fig. 4, is considered a scenario (O) for each facade. Then, other scenarios, despite the appropriate depth and distance for the louvre, are examined under 36 scenarios according to Table 6 The results of these studies are shown in Fig. 5 to 8. As can be observed in the southern facade of the building, according to Fig. 5, the presence of the louvre-shaped shading has been more suitable than the horizontal one. Moreover, the dimensions of the louvre have also been influential. According to the angle of the sun's height (60°), as the depth of the louvres increases, the amount of internal daylight also decreases, and this factor also creates an unsuitable visual environment for the users. The use of a low-depth louvre-shaped shading (Scenario A) is closer to its standard range in terms of the distribution of daylight factor (DF) in space and provides a more suitable visual environment.

Table 6. Simulation scenarios due to dimensions and reflection coefficient of louvres on each façade. Source: Authors.

Detail for Spindle Shape Aluminum Louvre with Rho=62%		Sunny Facade			
		Southern Façade (Horizontal Louvre) Dept of Blades (w)(cm)	**Eastern Façade (Horizontal Louvre) Distance between Blades (cm)(75%depth)**	**Northern Façade (Vertical Louvre)**	**Western Façade (Horizontal and Vertical Louvre)**
---	---	Horizontal shader Dimension=3*0.86m Angle=60 degree (O)	Horizontal shader Dimension=3*1.5m Angle=45 degree (O)	Vertical shader at the west of the window Dimension=1*1.5m Angle=70 degree (O)	Vertical shader all over the window Dimension=3*1.5m (O)
10	7.5	A	A	J	J
12	9	B	B	K	K
15	11.25	C	C	L	L
20	15	D	D	M	M
22	16.5	E	E	N	N
25	18.75	F	F	O	O
30	22.5	G	G	P	P
35	26.25	H	H	Q	Q
40	30	I	I	R	R
Reflection Coefficient (Rho)		14%	30%	45% 60%	70% 80%

On other facades, such as the northern front, the presence of low-depth vertical louvres (scenario J) is more efficient. According to Fig. 6, it can be said that as the depth of the blades increases, the light entering the room decreases and deviates from its standard range on this facade, despite the angle of 70° of solar radiation and the depth of the shading, which is 1m on the west side of the window.

On the eastern facade, as shown in Fig. 7, the use of shading with a slightly greater depth than its lowest level (scenario b) performs better. According to Fig. 8 on the western facade, the use of shading in front of all windows in an integrated mode allows much less light to enter than in the standard model, but in the case of louvres (scenario m), the performance has been more appropriate. Finally, the results of all these studies show that the use of louvres with their appropriate depth on all building facades for climates such as Isfahan with a latitude of 32° provides excellent results in terms of proper daylight distribution. The effect of using louvre-shaped shading has been well specified on the adequate distribution of daylight in space. In all studies, the appropriate range for DF has been considered in the standard range of 2% to 3%, and the performance of scenarios has been measured in this regard. Furthermore, the warm months and times of the year are considered items that can be covered throughout the year, depending on the angle of the sun's height. In June, when the sun's rays are at their maximum, the effect of the shading is more significant, and the light distribution is better so that in other months, the percentage of daylight factor is less.

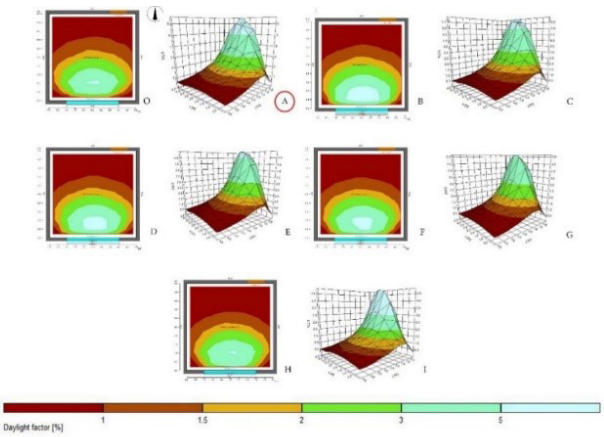


Fig. 5. Daylight distribution for various scenarios on the southern facade according to Table 6. Source: Authors.

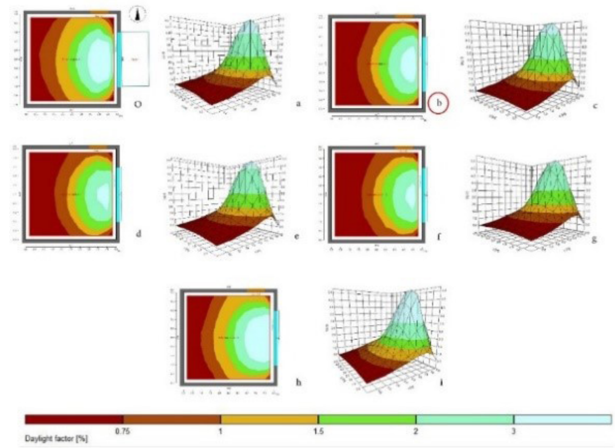


Fig. 7. Daylight distribution for various scenarios on the northern facade according to Table 6. Source: Authors.

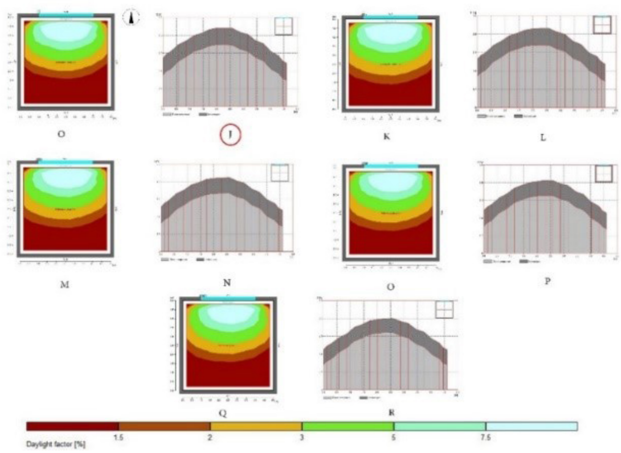


Fig. 6. Daylight distribution for various scenarios on the eastern facade according to Table 6. Source: Authors.

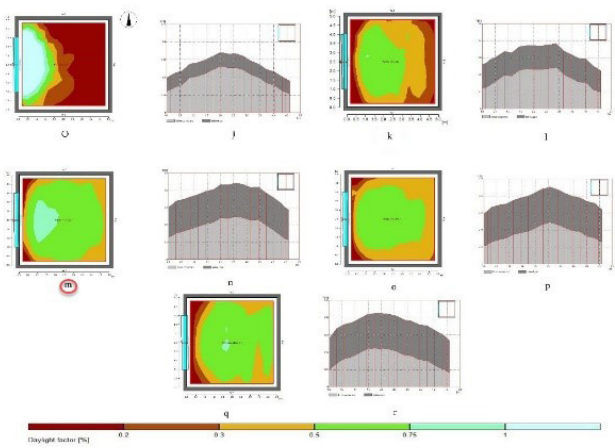


Fig. 8. Daylight distribution for various scenarios on the western facade according to Table 6. Source: Authors.

After obtaining the optimal depth for louvre shading in the case study, the effect of the reflectivity of louvre material has been examined. According to the standard materials used in the implementation of spindle-shaped louvres, the range of different reflectivity coefficients is considered in six scenarios. According to Table 7, the optimal dimensions obtained in each facade in six scenarios have been evaluated in terms of the Rho rate. According to Figs. 9 & 10, the results of the survey show that with increasing the reflection coefficient of the louvres, the DF level also increases and becomes closer to its standard range, so Rho = 80% has better results than other scenarios. It means that the type of material or even painting on the surfaces of the louvres can affect the existence of daylight in space and visually balance the environment for users. Using these four shading models in a climate such as Isfahan with a latitude of 32 degrees makes it possible to increase visual comfort and help enter better and more natural daylight in the space.

- **Visual quality indexes**

The maximum radial line (Rl (l)) in Isovist is an index that examines the length of the longest radius line seen from the observer station point. In this study, due to the observer's space, which is networked in the different points of interior space, and the average maximum radial of view with louvre shading in different scenarios based on Table 8 and Fig. 11, it is found that the space with south shading has a longer radial line. This result shows that in this scenario, the observer has the largest radius of view as well as a greater view of the surroundings than in other scenarios at any internal and designated point of space. Furthermore, according to Table 9 and Fig. 12, the space with south shading has a higher average of the Isovist area (A) index, which is the number of points that can be seen from the observer station point. Therefore, this scenario not only has a larger radial line (maximum radial line (Rl(l)), but also has a bigger area of observer view that the observer perceives clearly of the space (Isovist area (A)).

Pearson's test by SPSS software was employed to assess the relationship between research variables. Correlation or non-correlation was examined at significance levels of α=0. 01 and α=0.05. The correlation coefficient (ρ) indicates the strength and direction of the relationship between two variables. A value closer to 1 suggests a stronger positive correlation, while a value closer to - 1 indicates a stronger negative correlation. A ρ value of 0 implies no correlation. In the current research, according to Table 10, the test results reveal a significant correlation at a 0. 01 significance level between the visibility area and the maximum visibility radius of the Isovist. Particularly, the maximum visibility radius showed a positive and direct correlation with the Isovist area index, and both of these indicators display a positive and direct correlation with the Daylight Factor metric.

Conclusion

This article aims to provide visual comfort and better distribute natural light in architectural spaces with

Table 7. Details of the scenarios for the reflection coefficient of material louvres at optimal conditions obtained in the previous step. Source: Authors.

Facade	Optimal Louvre Dimension (cm)	Scenario	Reflection Coefficient (Rho)					
			(14%)	(30%)	(43%)	(80%)	(70%)	(60%)
Southern Facade	10*7.5	I	*	*	*	*	*	*
Eastern Facade	12*9	II	*	*	*	*	*	*
Northern Facade	10*75	III	*	*	*	*	*	*
Western Facade	12*9	IV	*	*	*	*	*	*

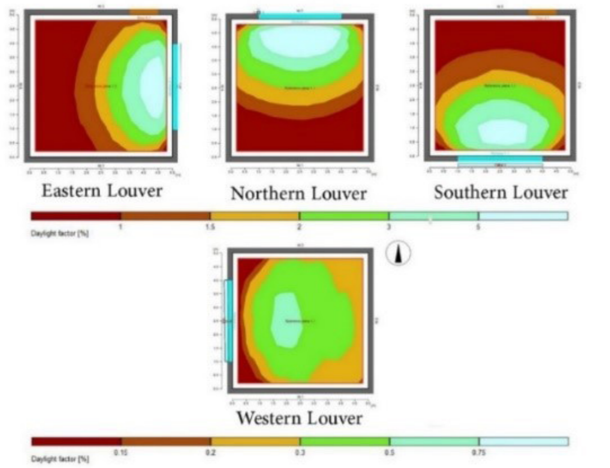


Fig. 9. Results of daylight distribution for the various scenarios according to Table 7. Source: Authors.

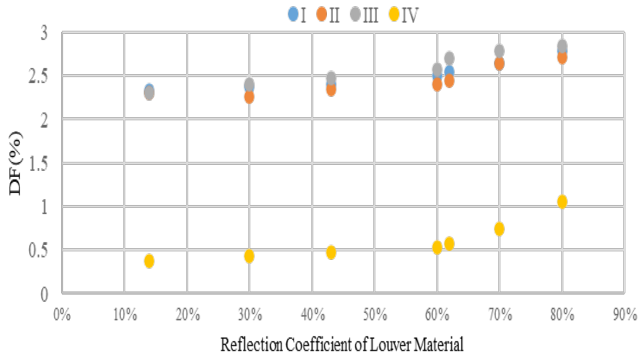


Fig. 10. The final results of the daylight distribution for the optimal dimensions and reflection coefficient in optimal louvre-shaped shading on the four facades of the case study. Source: Authors.

Table 8. Maximum radial line (RI) index for different scenarios. Source: Authors.

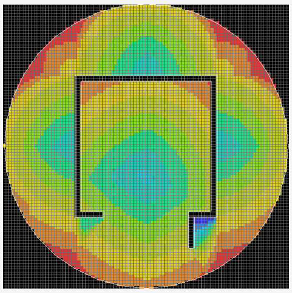
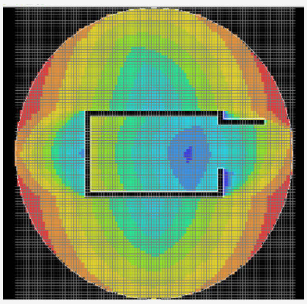
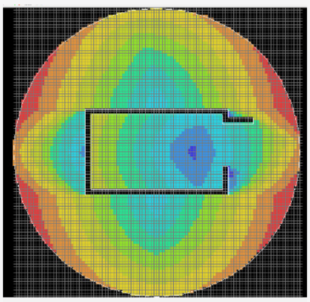
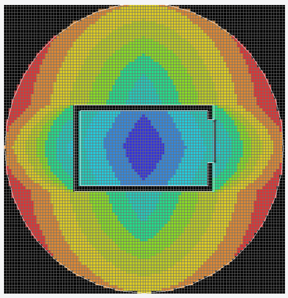
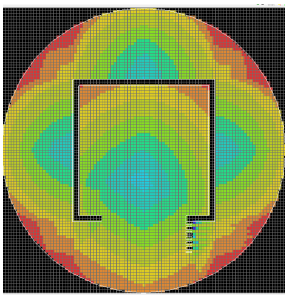
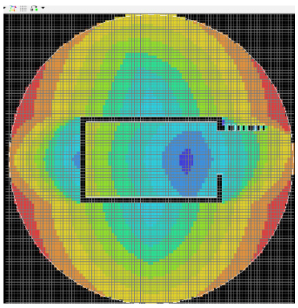
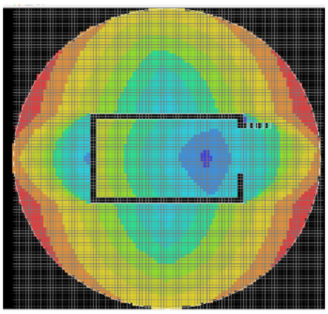
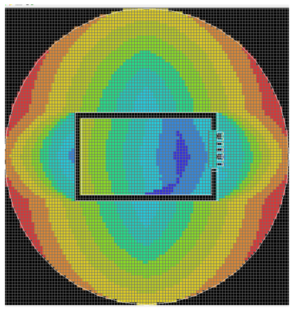
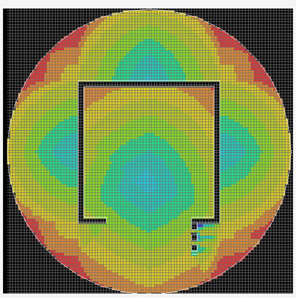
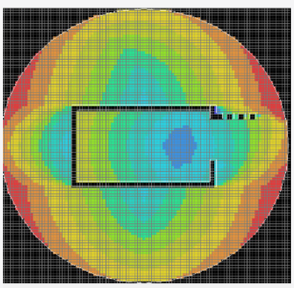
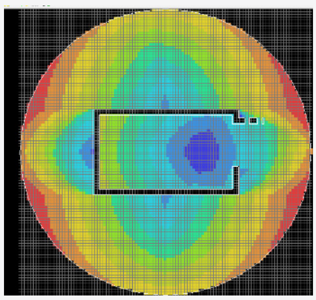
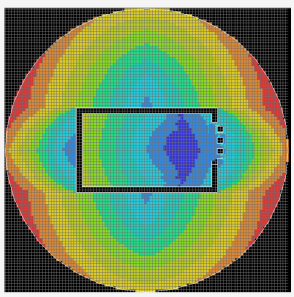
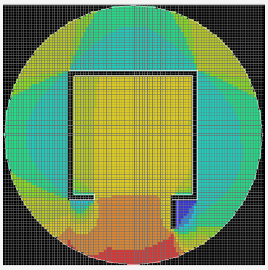
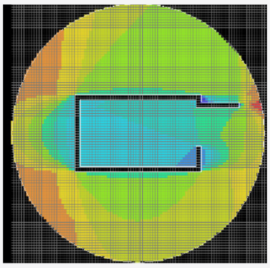
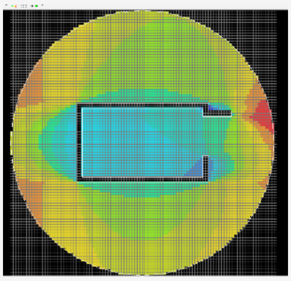
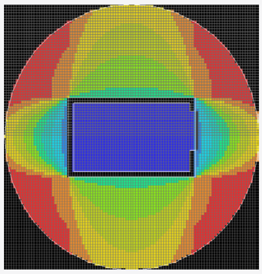
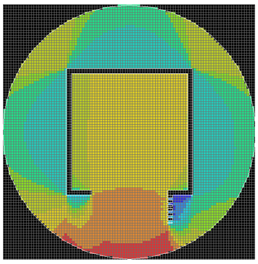
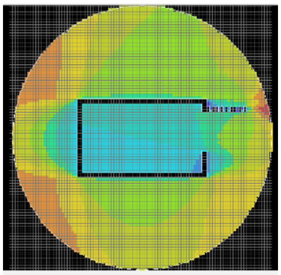
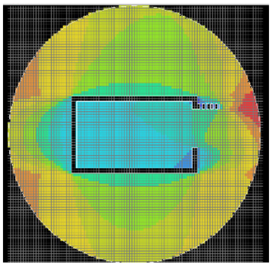
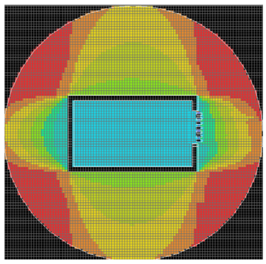
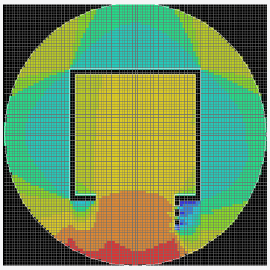
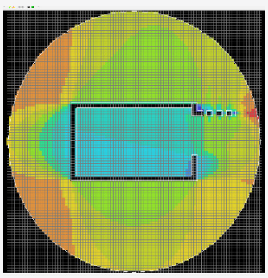
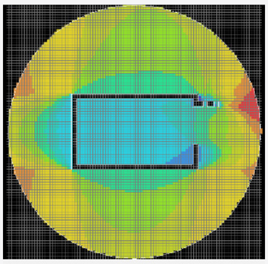
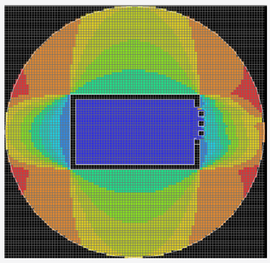
Scenario	Northern facade shading (plan)	Eastern facade shading (section)	Southern facade shading (section)	Western facade shading (section)
Simple shader without louvre				
Shader with 10 per 7.5 cm blades				
Shader with 22 per 16.5 cm blades				

Table 9. Isovist area index for different seniarioes. Source: Authors.

Scenario	**Northern facade shading (plan)**	**Eastern facade shading (section)**	**Southern facade shading (section)**	**Western facade shading (section)**
Simple shader without louvre				
Shader with 10 per 7.5 cm blades				
Shader with 22 per 16.5 cm blades				

an educational purpose in the hot and dry climate of Isfahan, Iran. Necessary studies are conducted about natural daylighting and shader types for exterior facades. In this study, daylight factor (DF) in space, maximum radial line (Rl (l), Isovist area as dependent variables, and the effect of dimensions and reflection coefficient of louvres as independent variables have been investigated by using simulation in Relux lighting software and the Isovist tool. During the study, field measurements are also used by the Lux meter, and in climatic-statistical studies, to validate and analyze the data, Climate Consultant 5.4, Excel, and SPSS software are used. After conducting the necessary studies and modeling in line with the objectives of the research, it has been concluded that for different facades of the building, different shading can satisfy the objectives of the study. First, the optimal dimensions for the louvres in each façade are obtained, and then the reflection coefficient of the louvre materials is examined. Finally, the results show the use of such shading can help better and more efficiently distribute daylight in such a way while controlling the unfavorable rays of sunlight. Also, in terms of the reflection coefficient of louvre materials, Rho = 80% can be the right amount of reflection for blades. In such a way that it leads to more balanced lighting and visual conditions. In addition, according to the study of Isovist indicators and the visual quality of the shadings, it is indicated that the southern louvre external shading provides a wider viewing radial and more visual perspective in the interior spaces. Hence, this study can recognize and optimize some cases in terms of shading and present their optimum conditions, profoundly affecting the visual comfort of users. However, simulations and investigations are conducted

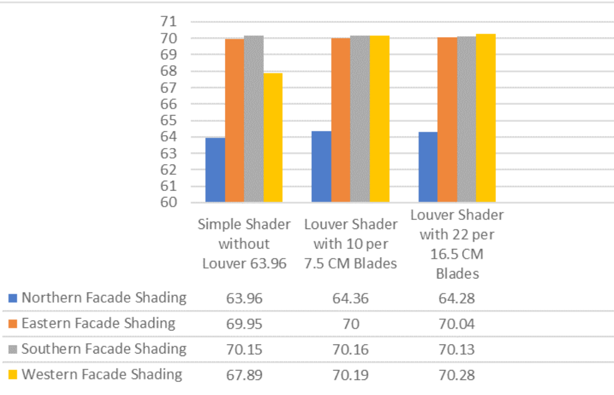


Fig. 11. Numerical comparison of the maximum radial line of sight index in different scenarios Source: Authors.

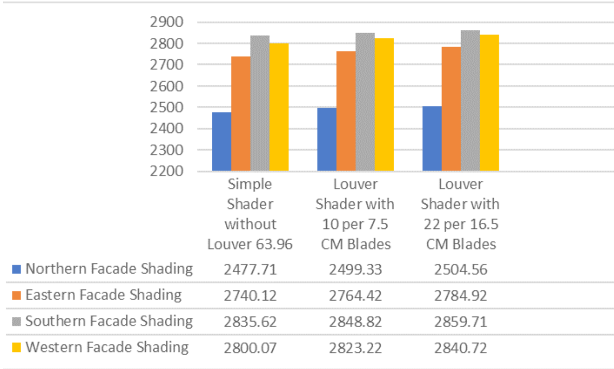


Fig. 12. Isovist area index in different scenarios. Source: Authors.

Table 10. Correlation results of daylight factor index and visual quality in different windows with considered louvres. Source: Authors.

Correlations			
	Isovist Area	Maximum Radial Line	Daylight Ratio
Isovist Area	1	0.982**	+0.458
Maximum Radial Line	0.982**	1	+0.449
Daylight Ratio	+0.458	+0.449	1
** Correlation is significant at the 0.01 level (2-tailed).			

in a particular climate (the hot and dry climate of Iran) for educational buildings, and climate changes may cause slight variations. It is possible to achieve a bright architectural space using natural daylighting and appropriate shading so that users' visual and thermal needs are met. Passive systems, such as exterior sunshades, which are a part of the architectural design of buildings, can thus provide a pleasant environment in terms of thermal comfort and the distribution of daylight in the space. The findings suggest that recommending a daylight-oriented design of louvre shading parameters for each facade orientation is advisable based on specific climatic conditions. This, in turn, responds to research questions properly.

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