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## CASE STUDY RESEARCH PAPER

### Contemporizing and Optimizing the Patterns of Iran's Traditional Skylights (Shabak) in Using and Improving the Quality of Daylight in Office Space

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#### ABSTRACT

A large share of energy consumption in office buildings is due to lighting. Energy efficiency improvements are currently attained through strategies that cut artificial lighting by intelligently utilizing daylight. Providing daylight and controlling glare in office buildings has always posed significant challenges for designers. In this regard, skylights play a crucial role in enhancing building performance by improving both daylight efficiency and occupants' visual comfort. The Shabak skylight, one of Iran's architectural elements, significantly provides light and intelligently uses daylight. This study explores Shabak skylight patterns that optimize performance to control daylight and glare transferred from windows. The research method of this study is descriptive and analytical. In addition to library and field studies, Rhino software, Grasshopper, Ladybug, and Honeybee plugins are used for simulation, and finally, a genetic algorithm is used for contemporizing and optimization. The results indicate that three main parameters (absorption point position, absorption impact radius, and scale of apertures) are effective in daylight gain, and variations in these parameters based on the optimized plan would lead to a 55% increase in useful illuminance of daylight and a 17.25% reduction in glare annually. The results of this study can be useful for applying these elements based on modern architecture regarding optimal optimization. By sharing their findings on the best methods to evaluate the performance of potential designs, this study will be valuable for architects designing Light-transmitting wall and patterned shade screens in similar climates.

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## INTRODUCTION

Energy consumption is one of the critical challenges in contemporary architecture worldwide, particularly in developing countries (Mahdavinejad et al., 2012). In the modern era, attention to the climate and its role in the design stages has undergone many changes. Studies show that emphasizing daylight's importance for intelligent energy consumption and efficiency has become a significant topic. Additionally, it is important to contemporize indigenous technologies in contemporary architecture (Mahdavinejad & Mator, 2012). Materially, contemporization is defined as an intervention in a work to create a creative dialogue between stable ancient values and high contemporary values (Aghaeimehr & Gharehbaglou, 2020).

The presence of light in architectural spaces throughout different historical periods, beyond its functional role in lighting and facilitating daily activities, has also been a significant spiritual element, widely considered and utilized in religious contexts (Mahdavinejad & Bemanian, 2013).

In recent decades, experts have emphasized the need to reduce energy consumption and recognized the positive physical and psychological impacts of daylight on users, incorporating daylight in buildings as a fundamental aspect of design. Consequently, various light emission patterns within indoor spaces and Light-transmitting wall have become significant architectural criteria that considerably influence human perception. Despite their effectiveness, it seems that architects are not systematically and precisely aware of the perceptual effects of light patterns within building interiors.









The light-transmitting wall can significantly impact spatial experiences by adhering to geometric criteria, patterns, and the rhythm of shadow and light. Additionally, daylight serves as a dynamic and crucial factor in enhancing the quality of indoor spaces, influencing the experience and perception of occupants (Abboushi et al., 2019; Chamilothoni, Wienold, et al., 2019; Moscoso et al., 2021; Rockcastle et al., 2017).





It is important to use daylight in building design to reduce energy consumption costs and improve the health, comfort, and productivity of individuals (Makani et al., 2012). Porous shells and multilayer façades are some solutions that improve daylight in a building's indoor space by using various geometric patterns (Rezaei & Sharghi, 2020). Now, the logical use of daylight seems essential for improving occupants' quality of life and increasing their satisfaction with architectural space. Paying attention to the teachings and experiences of ancestors regarding the suitable use of daylight in architectural spaces would enhance efficiency, improve the quality of indoor space planning, and promote energy saving.

As one of the important factors in shaping the appearance of a building, windows make a significant contribution to the architecture of different ethnic groups. The type and style of windows largely depend on the cultural and environmental characteristics of the area.

In past periods in Iran, light control in indoor spaces was highly significant for architects, so techniques and elements such as light controllers and skylights like Shabak were used. Now, with the development of new materials, smart technologies, and optimization techniques, we can present new solutions for modern control technologies. This study aims to revive the Shabak element and introduce new smart strategies for controlling daylight in spaces. By improving the quality and quantity of the Shabak element, we can maintain other features of interior lighting design. This research seeks to answer the questions: What is the effect of modernizing and optimizing the geometry of the Shabak pattern on Useful Daylight Illuminance gain? How and in what way does changing the distribution and scale of the Shabak apertures affect the uniformity of light in the environment? Consequently, the research hypothesizes that by choosing the correct geometric form and changing its distribution and location, the quality and quantity of Useful Daylight Illuminance gain can be optimized and maintained throughout the year.

**Table 1:** Elements related to light in Iranian architecture and their definitions and Efficiency of some lighting elements in the building (Belali Oskoyi et al., 2022; Nemat Gorgani, 2003; Zabihi & Yazhari Kermani, 2023)

Elements related to daylight control in the traditional architecture of Iran	Light controller	Portico	A covered columned space on one side is enclosed, protecting humans against rain and daylight.	protecting rain and daylight	
		Tabeshband	The curtains are made of straw installed on the external façade of the building on the windows that can be folded to adjust the light.	daylight supply, Natural ventilation, Daylight control	
		Sabat	The covered alleys are constructed in the cold and hot climates.	Natural ventilation,	
	Skylight-translucent	Sash window	A Shabak window opens vertically upwards and is located in a container.	daylight supply, Natural ventilation, Daylight control	
		Palkaneh	It is a porch or balcony surrounded by windows.	daylight supply, Natural ventilation, Daylight control	
		Jamkhaneh	The apertures placed in domes and bazareh	daylight supply, Natural ventilation	
		Shabak door and window	Doors and windows are constructed in Shabak form and different sizes in areas with severe irradiation.	daylight supply, Natural ventilation, Daylight control	
		Rozan	Small windows are often used on the top or two sides for solar gain.	daylight supply, Natural ventilation,	

Elements related to daylight control in the traditional architecture of Iran	Skylight-translucent	Roshandan	Some apertures in the shape of hats were created in public buildings such as Bazaars where windows could not be used on the walls.	daylight supply, Natural ventilation,	
		Shabak	A mesh surface consisting of filled and empty spaces to supply and soften daylight that can be seen from one side to the other.	daylight supply, Natural ventilation, Daylight control	
		Goljam	Some apertures were built on the high-top part of a room to provide light to indoor space using small and colored glasses.	daylight supply, Natural ventilation	
		Horno	The open pores and apertures are built on the ceiling to provide illuminance and air conditioning.	daylight supply, Natural ventilation	

Light-absorbing-light-transmitting elements	Visual Comfort		Energy efficiency		Natural ventilation	Beliefs
	privacy protection	glare protection	daylight supply	Daylight control		
Aperture	-	+	+	+	-	-
Shabak	+	+	+	+	+	+
Goljam	-	+	+	+	-	+
Shabak doors and windows	+	-	+	+	+	-
Pachang	+	-	+	-	+	-
Frizkhooon	-	-	+	+	+	+

In the Shabak element, both practical and aesthetic aspects have been considered (Eskandari et al., 2018). Among the skylight elements used in traditional Iranian architecture, the Shabak element served purposes such as visual comfort, privacy protection, glare reduction, energy efficiency, daylight supply and control,

natural ventilation, and reflecting Iranian beliefs (Oghazian, 2017). According to available field assessments, the most frequently used geometry of Shabak is the chalipa geometry, found in buildings with various uses, especially in Iran's hot and dry climate (Tab. 2)

**Table 2:** Sample of Shabak skylight and geometry of chalipa used in buildings of Kerman City (Source: Authors)

		
<p>Shahzadeh Garden in Kerman</p>	<p>Yazdanpanah House in Kerman</p>	<p>Shah Nematullah Vali in Kerman</p>

### *Geometry of chalipa*

Chalipa has held significant importance in the architecture and art of Iran since ancient times. The background and history of this motif trace back to the Neolithic period in Iranian pottery. The chalipa image divides space into four parts with a point at its center. Various images of chalipas in pottery and stone inscriptions found in ancient sites are presented in Table 3. Chalipa is a geometric motif or pattern placed on a squared base and is considered a symbol of the sun among people (Kafshchian Moghadam & Yahaghi, 2012). The significant meaning of the chalipa motif has led artists and architects to use this motif throughout the history of Iranian architecture in various ornaments of buildings across different historical periods (Heidari, 2022).

The geometric motifs used in Shabaks, especially the chalipa geometry, which has a long history, were not only used for beauty but also to make the most of daylight. This design causes the direct light of the sun to spread in different directions, directing it into the space. It also prevents the eyes from getting tired from strong direct light and adjusts the light inside the space (Tab. 3)

### *Daylight*

The definition proposed by the CIE: Commission Internationale de l'Eclairage, mentions three factors concerning daylight intensity: daylight quality, daylight quantity, and glare. Additionally, access to visual comfort in indoor environments depends on two parameters: uniformity

and glare. Since scattered and uniform light can provide more energy savings and visual comfort, these two parameters must be considered in illuminance design. (Mahdavinejad & Kia, 2019). In the design of space illuminance, uniform light distribution is critical. This reduces glare and improves visual comfort. Small, non-centralized apertures can be used on walls and screens to achieve this purpose. (Lechner & Cooling, 2001).

### *Spatial Glare Autonomy (sGA)*

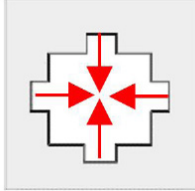
High levels of daylight luminosity in the environment cause glare and reduce visual comfort. This lack of visual comfort and the presence of glare can negatively affect individuals living in the building's environment (Christoffersen, 2000). sGA is the fraction of views in a space that are visually comfortable (Lu & Tzempelikos, 2024).

### *Useful Daylight Illuminance (UDI)*

The UDI is one of the dynamic daylight indicators. It is measured based on the illuminance rate of the worktable. This factor can create a distinction between different illuminance rates. An illuminance rate of less than 100 Lux cannot be effective and sufficient for doing visual duties. Hence, a space with such a rate of illuminance needs to use artificial illuminance. In contrast, the illuminance rate greater than 3000Lux may lead to a lack of comfort among occupants, glare, and increase heat in the environment (Brzezicki, 2024; Nabil & Mardaljevic, 2005).

These values may become more or less in some areas under specific conditions. The IES

Table 3: Geometry of chalipa used in buildings and decorations of ancient Iran

<p>Naqsh-e-Rostam Chalipa pattern</p> 	<p>Persepolis Chalipa pattern</p> 	<p>Plaster work of Tisfoon Palace with Chalipa and broken chalipa pattern</p> 	
<p>(Mohseni &amp; Bastanfard, 2020)</p>		<p>(Ghaem, 2009)</p>	
<p>Ashoor Palace, chalipa-pattern</p> 		<p>Pasargad, chalipa pattern</p>  	
<p>(Pirnia &amp; Memarian, 2004)</p>			
<p>geometry of Chalipa used in the clays and inscriptions discovered in the ancient area</p>  <p>(Bakhourtash, 2001; Vandenberg, 1969).</p>		<p>Niasar Fire Temple, chalipa pattern</p>   <p>(Mohseni &amp; Bastanfard, 2020)</p>	
<p>Shabak with the geometry of chalipa in Sheikh Lotfollah Mosque, Isfahan</p>   <p>(Arel &amp; Öner, 2017)</p>			

illuminance handbook generally defined the values 100-1500Lux as acceptable rates. According to the recommended range of IES for office spaces, the considered illuminance rate was

regulated between 300 and 1500 Lux (Bahdad & Fadzil, 2022; Clayton, 1948; Razzaghmanesh, 2015). Table 4 reports some studies conducted on this topic.

**Table 4:** Review of conducted studies

Reference	Simulation tool	Measured factors	Findings
(Wagdy et al., 2015)	Grasshopper Diva	Evaluate annual daylighting performan,	Specific optimization and configuration of the façade based on origami create opportunities for improving daylight quality and energy savings.
(Emami & Giles, 2016)	Rhino Diva Flamingo	Illuminance, glare	Four Iranian patterns were contemporized. Illuminance surfaces were decreased by downsizing the aperture ratio. The ratio and size of the apertures affect the reduction of glare.
(Safaetabar et al., 2018)	Grasshopper Honeybee Galapagos	Daylight illuminance, glare	Lighting reaches the optimum level by adding a shell to the first and second floors, and glare is considerably reduced on the fourth and fifth floors.
(Tabadkani et al., 2018)	Rhino Grasshopper Diva	Evaluate annual daylighting performan, visual comfort	The results indicate that the proposed model significantly improves daylight and glare criteria to achieve maximum visual comfort.
(Abboushi, 2018)	Autodesk revit	Visual interest Of daylight patterns, and view quality Visual comfort	Three types of daylight emission patterns were examined. Fractal emission patterns significantly affect visual attraction, visual preference, and light quality.
(Chamilothori, Chinazzo, et al., 2019)	Rhinoceros Radiance Diva	Daylight illuminance, occupant subjective perception , physiological responses	Compared to regular geometry, irregular geometry significantly enhances feelings of pleasure, attraction, excitement, and light uniformity.
(Jalali et al., 2020)	Grasshopper Honeybee Ladybug	Daylight illuminance, Energy use	Optimizing the south facade using a genetic algorithm has led to a 50% increase in UDI space and a reduction in the emergency load.
(Pilechiha et al., 2020)	Rhinoceros Grasshopper Honeybee Ladybug Energyplus Open studio Octopus	Energy use intensity (eui) Quantify and evaluate annual daylighting performance, sDA and ASE metrics are utilised Quality of view	The multi-objective optimization results show the maximum possible window-to-wall ratio for the reference room. To achieve the specified lighting and visibility requirements, the room geometry and window location should be adjusted.
(Bazazzadeh et al., 2021)	Grasshopper Honeybee Ladybug Energyplus	Daylight illuminance, Energy use	The optimization of light and energy reception revealed that dynamic shades are more efficient than fixed shade devices in terms of energy efficiency, visual comfort of residents, and the use of daylight.
(Valitabar et al., 2022)	Grasshopper, Galapagos Octopus	Visual comfort (daylight and glare)	The simulation findings of the proposed control system indicate that reducing glare improves daylight performance by 44%.
(Maroofi et al., 2023)	Grasshopper Honeybee Ladybug Energyplus Galapagos	Daylight illuminance, Energy use	Optimization using a genetic algorithm and a sustainability approach has improved usable space, reduced heat load, and enhanced daylight in the building.

**MATERIALS AND METHODS**

The current research consists of two stages: library, field, and simulation studies. The first stage involves evaluating the features and performance of the Shabak skylight in Iran's hot and dry climate through library and field studies, as well as obtaining the geometry used in Shabak. The second stage uses the data obtained from these studies to perform simulations of space geometry in Rhino and Grasshopper, which have parametric modeling capabilities, and employs the Galapagos tool to optimize a function based on the evolutionary (Genetic) algorithm. Subsequently, settings related to the reflection values of the surfaces and analysis sensors were configured using Honeybee. Finally, the model was sent to the Radiance Simulator for simulation (Fig. 1).

Simulation and analysis of the selected method The dimensions of the reference model were chosen based on the common dimensions obtained from Yazhari's study (2019), which was conducted in the administrative offices of Kerman City through a field survey and registration of 220 office rooms (Yazhari Kermani, 2019). Consequently, since the analyzed space is part of real-world research, the office space was selected and modeled in Rhino with dimensions of

5.36×10.36 meters and a height of 3.63 meters, featuring three windows with similar dimensions of 1.8×2.46 meters oriented to the south in Kerman, which is located in a hot and dry climate. The length, width, and height of this room are respectively, which are the dimensions of a standard office room in Iran (Hakimazari et al., 2024). Given the office building's location in Kerman City, meteorological data from Kerman, extracted from climate.one.building.org, were used for all simulation steps. This website is one of the most important meteorological files. To examine and calculate different indicators in the space, sensors were placed at 0.5-meter intervals at a height of 0.76 meters (the height of the user's table) (Fig. 2).

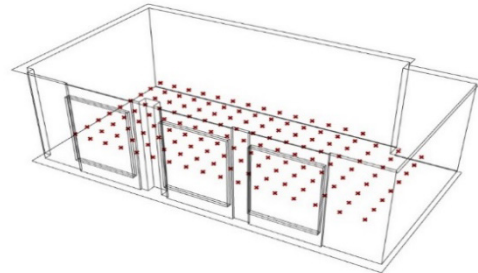


Figure 2: Simulation of office space

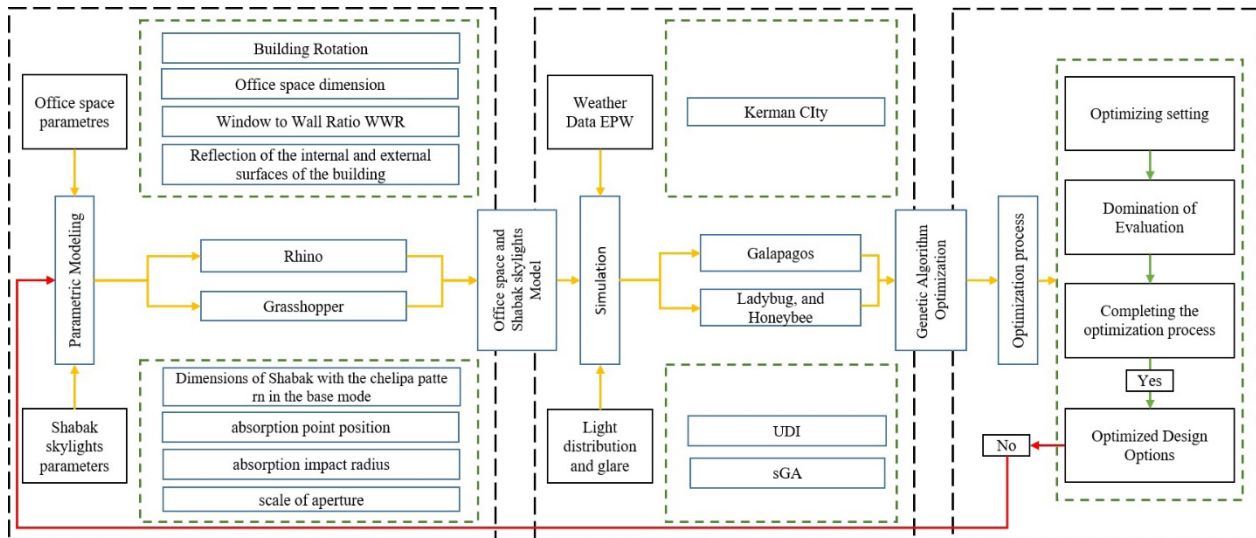


Figure 1: Research workflow

The values for the daylight and glare indices, related to the reflection of the internal and external surfaces of the building, were set according to the National Building Regulations of Iran, Topic Nineteen (Tab. 5).

Table 5: Materials properties for daylight simulations

Building Component	Reflectivity
Walls and partitions	0.5
Floor	0.2
Ceiling	0.7
Ground	0.2
Exterior Walls	0.3

Software Validation

Field sampling was done to validate the results during the two equinoxes (20th Mar and 23rd Sep). The intensity of illumination at three

points the first half of the model (A), the center (B), and the last half of the model (C) was measured and recorded at 9:00 AM and 3:00 PM using a lux meter. Similarly, the dimensions of the room in the existing state, along with all necessary details, were modeled in Rhino software and analyzed with Radiance software. The light intensity at the three points (A, B, and C) was measured at 9:00 AM and 3:00 PM (Fig. 3)

The numbers read by the lux meter are compared with the simulated room sample and presented in Diagram 1. From the comparison of the results obtained from the data collection and computer simulation, it can be concluded that the simulation results are close to reality, making Radiance software a suitable choice for continuing the research path.

According to the study's objectives to optimize the modes of Shabak, the illuminance rate



Figure 3: Right Image: Office Space, left Image: Radiance software

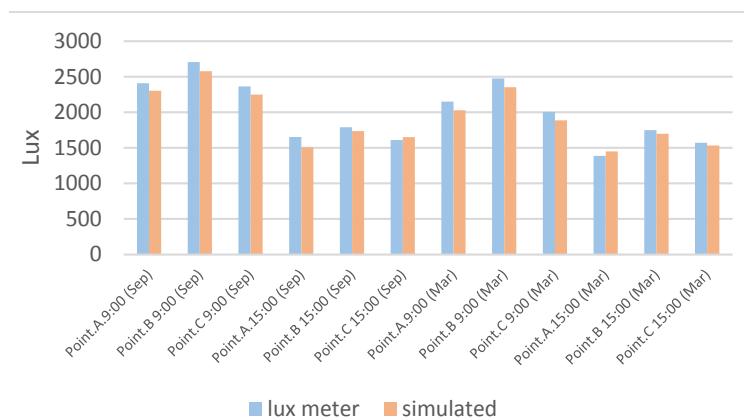


Diagram 1: validate 20th Mar and 23rd Sep

index has been used. Calculation and evaluation of this index were done based on the LEED Standard. According to this standard, the simulation was carried out at 9:00 a.m. and 3:00 p.m. during the equinox. Based on the results of the literature review and the potential for higher rates of glare at values close to 3000 lux, the upper limit of this range is considered to be 1500 lux in this study.

After determining the space dimensions, the genetic algorithm was first used to optimize the UDI and sGA over a one-year interval to achieve a standard level of UDI and minimal glare throughout the year. In the next step, the geometry of Shabak was modeled through Grasshopper (Fig. 4). Based on the data obtained from daylight optimization, the extensive range of apertures on the façade was examined, the daylight gain rate was calculated, and it was finally compared with the previous mode.

#### Optimization

To perform optimization, the relevant indicators and parameters must be determined. For this purpose, the rates related to space shape and window size were considered fixed. Shabaks can be placed on windows in different combinations. To create various states of the Shabak and its empty spaces, three main parameters have

been considered. Various shapes of empty spaces in the Shabak are created around one point. Therefore, the first parameter is the location of the absorption point, which determines that the pattern of empty spaces in the Shabak becomes larger as the distance from the absorption point increases. The closer we get to this point, the smaller the patterns become. The second parameter is related to the absorption impact radius, measuring the intensity of

absorption. The higher this value, the more the patterns farther from the absorption point will be affected. The smaller this radius, the less the distant patterns will be affected. The third parameter is related to the maximum size of patterns. Patterns farthest from the absorption point and unaffected by it can have various sizes. The parameters related to Shabaks or each window are separate and independent. In other words, three absorption points will exist, and the location of each window will change independently. In total, 45 points are considered on each window where an absorption point can be placed. These points are spaced 40 cm apart to obtain the maximum possible modes because decreasing the distance between points would exponentially increase the possible modes (Tab. 6).

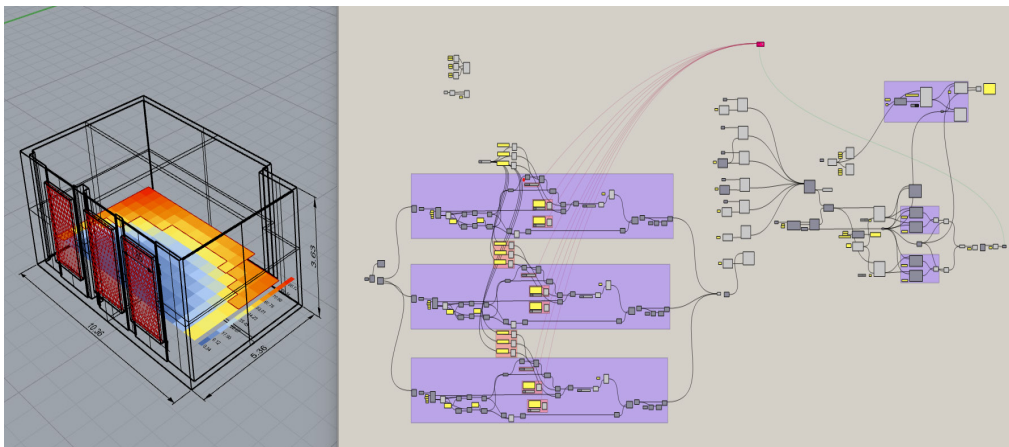


Figure 4: Optimization algorithm of useful daylight within the one-year interval

The maximum dimensions of the patterns not affected by absorption points are shown in Table 7.

Table 7: Various values considered for Shabaks's absorption radius

Name	Max	Min	Variations steps
Absorption radius (m)	0.7	1.1	0.2

In total, three modes are considered for this parameter, with smaller dimensions for the other two modes, and their specifications are reported in the table below. It is worth noting that

these values are considered for the possible use of smaller or larger patterns. Three modes have been considered for the absorption radius and scale of patterns, with the maximum and minimum values reported in Table 8. The minimum radius considered for the effect of surrounding patterns is 70 cm<sup>2</sup>. Considering three values helps control the number of possible modes in the optimization process. If the number of parameter modes is not controlled, the possible modes may reach billions, making it impractical to reach optimum solutions.

Table 6: Modeling Shabaks on the space's windows

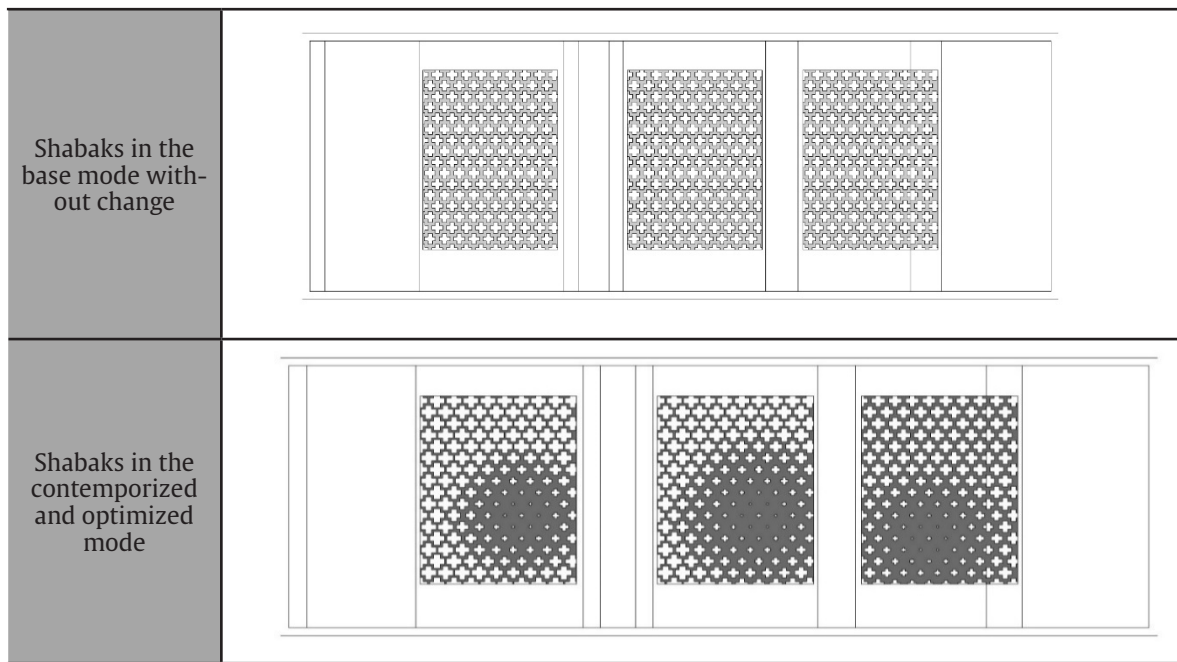


Table 8: Studied scales for different modes of Shabaks

Title	Maximum scale	Moderate scale	Minimum scale
Area (Cm <sup>2</sup> )	207.36	156.79	122.69
Image			

#### *Optimization tool*

Considering the range of changes for each parameter, there will be about 66 million states, which are practically impossible to check one by one. Therefore, optimization algorithms such as evolutionary algorithms have been selected because they can achieve optimum solutions by assessing fewer modes. Since the Grasshopper environment has a tool for optimizing single-function genetics, this tool can be optimally used in combination with Honeybee to extract results and achieve ideal optimization. Grasshopper and its parametric modeling help us create a suitable model of the environment and Shabak compositions, making the variation of modes and parameters possible using an optimization tool.

The Grasshopper Galapagos tool is responsible for single-function evolutionary optimization and alters the variables to provide various modes of compositions. The created models are then examined through Honeybee to extract the daylight results, which are used to determine the optimization process through Galapagos.

#### *Inputs of evolutionary optimizer*

Evolutionary optimization algorithms reduce and determine the optimal solutions by evaluating a finite number of random models. This process begins with the examination of the first generation, which is selected randomly. The results of the evaluated first-generation models serve as the criteria for creating the next generation and continuing the optimization process. In the next generation of models, integrating random and finite models creates better solutions than the previous generation. This process continues until no better modes and results are available, and optimal solutions are extracted. According to the presented explanations and the large size of the studied sample, 500 samples were selected for the first generation, and their examination took around 420 minutes. In the subsequent generations, simulated modes of 100 models are considered, of which 75 models are selected based on the results of the previous

generation, and 25 models are chosen randomly. This process continues in all subsequent generations until the optimization results are finalized.

#### *Optimization Findings*

After determining the parameters' values, optimization indicators are calculated using Galapagos; as shown in Table 9, 71 generations were performed to find and converge on the optimal solutions. In the early stages of the process, extensive optimization occurs in the compositions of parameters, requiring sufficient time to reach the optimum solution areas so that optimization can continue.

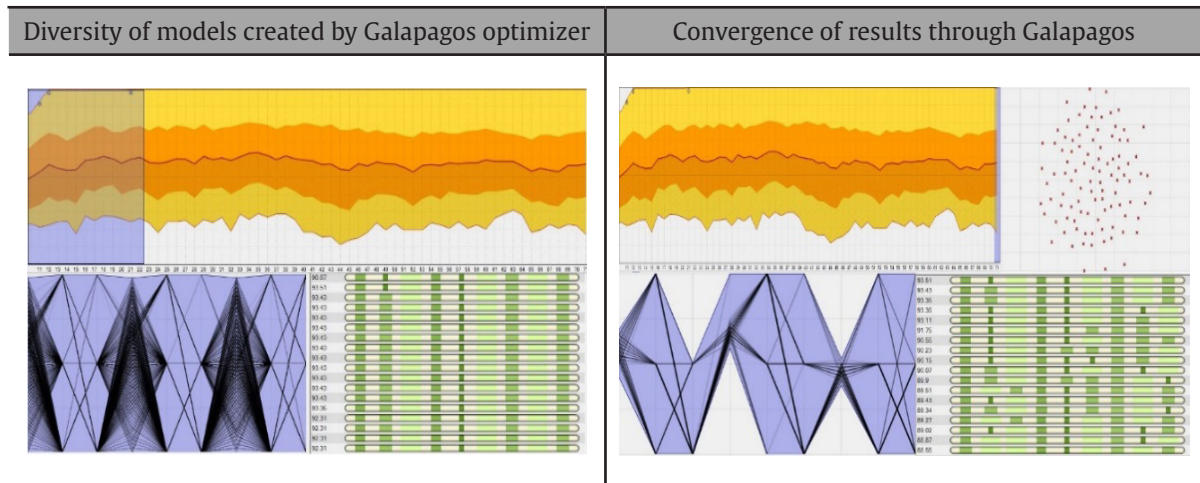
The areas where optimal solutions exist for each parameter indicate that appropriate results are obtained from different combinations of parameters. All data related to parameters and optimization functions are recorded and stored until the best modes are determined in the next step using Excel software based on the optimization function. In total, 7,600 separate modes are measured to reach the optimum solutions through the software.

According to the optimization results, the highest value obtained for the optimization function is 93.51%, indicating the percentage of space area where daylight received ranges between 300-1500 Lux during space occupation. The weakest value obtained and removed in the optimization process was 75.33% of the space. This lowest mentioned value is related to the optimization process, while the weakest modes have lower values if all modes are calculated.

### **DISCUSSION AND FINDINGS**

Using daylight to reduce energy consumption and increase the efficiency of daylighting in buildings, especially office buildings, has attracted the attention of many researchers today. This study aimed to investigate the effect of the Shabak skylight on UDI and glare in the space. In the first part, an office space with three similar windows was investigated and simulated in Rhino. Grasshopper parametric tools were used to create different states of Shabak combinations.

Table 9: Results of optimization



The Galapagos tool was employed to optimize a function based on a genetic algorithm. Finally, the evaluation was conducted using the Honeybee tool and Radiance simulation engine.

The investigation results for the top 100 modes showed that the UDI values ranged from 81.74% to 91.04%, reflecting a 10% difference. Similarly, the values for spatial glare autonomy ranged from 63.42% to 67.17%. Therefore, the best criterion for choosing among the best states is the UDI, which has a more significant difference in results. Finally, four modes

with UDI values over 90% were selected for comparison with the existing situation, and their characteristics are listed in Table 10.

By comparing the UDI and glare of the selected models and the primary mode, the excellent performance of the Shabaks becomes clearer. In other words, due to the proximity of the results of daylight and glare in the selected modes, the overall UDI has increased by about 55%, while glare in the space has decreased by about 17.25%. In Table 10, the results of the images obtained from UDI and glare analysis for selected states and primary states are displayed side by side. Based on the 3D results, optimal mode one has performed better in providing daylight; only a small part near the windows has received more intense daylight. For the glare index, the chang-

es in the selected states are relatively small, and the areas with glare are almost similar. This contrasts with the primary mode, where glare is present in virtually every space and is limited to the proximity of the windows in optimal conditions.

*Current mode*

According to the results presented in Table 11, for the selected indicators, the illuminance value within the desired range was 41.04% in the current situation. The end parts of the space have daylight within the appropriate range, while the areas near the windows have much more intense illuminance, exceeding 20,000 lux. The UDI index value, indicating illumination in the range of 300 to 1500 lux for at least 50% of the hours the space is occupied, was about 35%. Additionally, about 50% of the space experiences glare conditions. As indicated in the 3D image of this area, high glare exists when the cameras are directed towards the windows.

*Base Shabak mode*

Shabaks in the base condition and without an absorption point outperform the mode without Shabak. The glare index in this mode shows a 16% increase, while the UDI area shows around a 48% improvement. In comparison, the UDI index rate, which received 300-1500 lux illuminance

Table 10: Light distribution and glare in Top 3 modes

Optimal model	UDI 300-1500lux intervals (50%)							sGA				
01	<p>91.04%</p>							<p>65.17%</p>				
02	<p>90.87%</p>							<p>67.17%</p>				
03	<p>90.04%</p>							<p>64.42%</p>				
Optimal model	PW1	RW1	SW1	PW2	RW2	SW2	PW3	RW3	SW3	Bo	UDI	sGA
1	29	1.1	0.1	31	1.1	0.115	21	1.1	0.1	91.99	91.04	65.17
2	30	1.1	0.1	31	1.1	0.115	20	0.7	0.115	91.43	90.87	67.17
3	29	1.1	0.1	30	1.1	0.1	21	1.1	0.1	93.35	90.4	64.42
<p>* P: Location of the absorption point, R: Absorption radius, S: Scale patterns  W1: Left window, W2: Middle window, W3: Right window  Bo: Brightness optimization function</p>												

for at least 50% of space occupation hours, was around 83.19%. According to the results of the base mode, around 33.75% of the space experiences glare conditions.

#### *Optimum Shabak mode*

The UDI index rate, which received 300-1500 lux illuminance for at least 50% of space occupation hours, equaled around 91.04%. According to the 3D image of the UDI index, the end part of the space indicates suitable lighting conditions. In contrast, this index becomes smaller for each point closer to the window, dropping to less than 0.94% of space occupation hours when near the window. According to the results obtained in optimum Shabak mode, around 17.25% of the space showed a reduction in glare compared to the current mode (Tab. 11).

## **RESULT AND CONCLUSION**

According to the data and software output presented in Diagram Table 7, optimizing the Shabak skylight indicates a considerable increase in UDI within the 300-1500 Lux interval in base Shabak mode and particularly optimized Shabak compared to the current mode. It has also led to a reduction in glare, which can be considered the most important achievement of this research. In light of the energy crisis of recent decades, these results can increase efficiency and reduce the costs of illumination in office buildings. The investigation results for the current situation indicated that some parts of the room have little light, while others have excessive light, especially near the window. The UDI analysis data showed that the studied room receives useful lighting for less than 36% of the total occupancy time. In contrast, the optimized Shabak mode receives useful lighting for more than 91% of the room's environment during daylight hours, showing a 55% increase in UDI. Similarly, the glare anatomy analysis results indicated that the studied room currently experiences glare conditions for more than 50% of the occupied hours, whereas in the optimized Shabak mode, glare conditions are present in less than 34% of

the space. The analysis results of UDI and glare data in this study align with the studies by Tabadkani et al. (2018), Chamilothori et al. (2019), Jalali et al. (2020), Bazazzadeh et al. (2021), and Valitabar et al. (2022), indicating that simulating and optimizing light-transmitting windows using geometric patterns and control systems can improve the amount of UDI in the space. It also lays the groundwork for reducing glare and enhancing the visual quality of the interior.

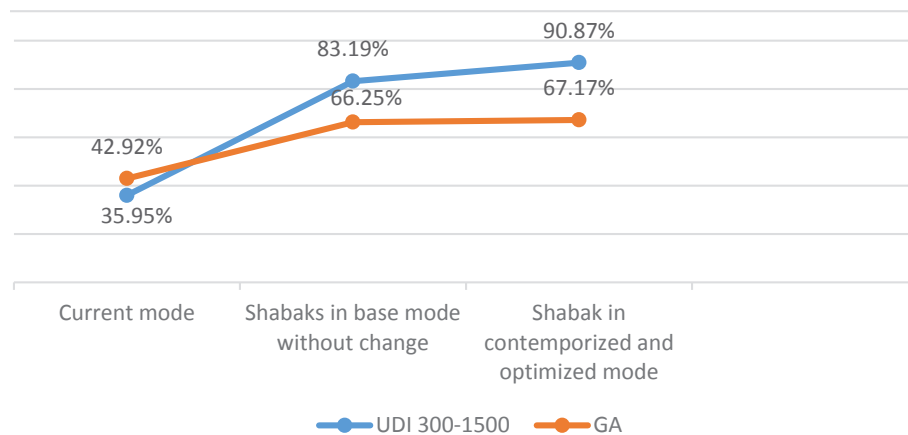
In the current study, the Shabak element was investigated with the aim of making contemporary architecture more efficient, especially considering the energy crises of recent decades. This efficiency draws from optimal reception of daylight and energy consumption optimization, much like traditional practices. Geometric patterns can be applied to windows in architectural spaces, serving not only as decorative features but also as environmental control systems that moderate daylight. The simulations showed that the most important function of the Shabaks is controlling the interior space from changing weather conditions and allowing softened daylight to enter in hot and dry climates. The Shabaks are based on Iranian geometry, which features repeating patterns. Therefore, any change in the position and scale of the apertures directly affects light performance. This prediction model uses three main parameters: absorption point position, absorption effect radius, and aperture scale. The location of the absorption point and the radius of the absorption effect are not the only factors influencing lighting performance; the aperture scale also significantly affects daylight performance in buildings.

In response to the research questions, the modernization and optimization results showed that changing the position and scale of the Shabak apertures significantly increases efficiency, causing a 55% increase in the annual average of receiving UDI, light uniformity, and a 17.25% decrease in glare. Today, by reusing this element, besides preserving cultural and architectural values, it can address the energy crisis

Table 11: Examination of light distribution and glare

Title	UDI 300-1500lux intervals (50%)	sGA
Current mode	35.91% 	49.92% 
Shabaks in base mode without change	83.19% 	66.25% 
Shabak in contemporized and optimized mode	90.87% 	67.17% 

Comparison of UDI and glare in three current, Current mode, Shabaks in base mode without change and Shabak in contemporized and optimized mode



effectively. Additionally, based on parametric research conducted in this field, it is possible to make the Shabaks intelligent and turn them into fully automatic systems that respond to environmental changes. Optimization results can indicate whether different optimal modes are worse or better and serve as a valuable guide for decisions in the design process. By informing their findings about the most suitable method of evaluating the performance of possible designs, this study will be valuable for architects designing light-transmitting walls and patterned shade screens in similar climates.

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