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Investigating performance illuminance-based metrics in evaluating the lighting condition within Architectural design studios according on users' activity type

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Abstract

Proper daylight utilization in educational spaces enhances energy efficiency and positively influences performance, focus, and the quality of students' learning. The primary objective of this research is to assess the precision and validity of daylight metrics in evaluating lighting conditions within educational spaces emphasis on activity type. A field study involving measurements and questionnaire surveys was conducted in six architectural studios from two architecture schools based in Isfahan City to assess user satisfaction with lighting conditions. The daylight and glare metrics were calculated through simulation and compared with occupants' responses and on-site measurements.The research findings reveal that among the static metrics employed to predict light quantity, the strongest correlation with user satisfaction is associated with the Ep threshold of 250-500 lux for paper-based activities. Conversely, users demonstrated the highest satisfaction within the Ep threshold range of 150-200 lux for mainly computer work. Among the dynamic metrics, a significant positive correlation exists between user satisfaction and the useful daylight illuminance (UDI) values of 100-300 lux for mainly computer work and 300-3000 lux for mainly paperwork. Metrics such as UDIe, ASE, and sDG exhibit a significant negative correlation with user responses, indicating the occurrence of annoying glare.

Keywords: Daylight;User satisfaction; Illuminance-based metric; Simulation; Field search

1. Introduction

Approximately 14% of the total energy consumed in an educational building is attributed to lighting(Mott, Robinson, Walden, Burnette, & Rutherford, 2012). This practice conserves energy and enhances user satisfaction by improving visual and thermal comfort within the environment. Furthermore, it plays a crucial role in regulating the circadian rhythm of the users, a process heavily reliant on the amount of daylight received (Tabadkani, Roetzel, Li, & Tsangrassoulis, 2021). Additionally, it has been demonstrated that maximizing natural light can enhance the performance and productivity of students. Among various educational spaces, ensuring visual comfort related to natural light in architectural design studios is paramount importance. This is due to the diverse activities conducted by students, including tasks involving paper and computer work, each necessitating different levels of desired illumination. Moreover, the extended duration of students' presence in the workshop and the broad age spectrum of users, including professors and students(Bellia, Musto, & Spada, 2011), demand special attention. To attain suitable natural light conditions in these spaces, adapted to their intended use and the prevailing climate, it is essential to define these conditions precisely and accurately assess light performance to prevent any visually disturbing conditions for users.

In recent years, various metrics have been employed for assessing daylight by standards and rating systems such as LEED, BREEAM, IES, and EN 17037. These metrics, classified into static and dynamic categories, differ in accuracy, simplicity, and their evaluation's time and spatial scope. Static metrics provide evaluations for a limited time frame and involve calculations for a fixed situation. Conversely, dynamic metrics consider design parameters, climatic conditions, and variations in the sky's state, consequently evaluating daylight conditions and visual comfort throughout the year based on meteorological data. As a result, they offer more comprehensive insights into lighting conditions (Reinhart, Mardaljevic, & Rogers, 2006). Thus, selecting an appropriate metric to assess the lighting conditions in a space that aligns with the geographical location, climate, usage and type of user activity can assist designers and

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operators in achieving their objectives for harnessing daylight effectively.

Research Objective:

- ✓ Investigate the visual comfort of the users, related to the sufficient entry of daylight and uniformity and the presence of views without disturbing glare, according to their **main activity** in architectural design studios by comparing the students' subjective evaluation with results of evaluation of metrics (**a board range of daylight metrics**).
- ✓ Evaluation of the lighting conditions of the space with daylight metrics that lead to the optimal design of the space and **reduction of energy consumption.**

Research Questions

- ✓ Which of the metrics regarding the sufficiency of daylight and the intensity of annoying glare provide a more accurate interpretation of user satisfaction in the educational space?
- ✓ To what extent does the type of user activity affect the level of user satisfaction with the amount of light and the intensity of glare annoyance?

2. Research Background

Due to the extensive and diverse research conducted in daylight-related visual comfort, this section will solely focus on recent research in educational spaces. The objective is to assess the quality of two significant and influential factors within this domain: the adequacy of natural light levels and the mitigation of disruptive glare. These assessments are made through the utilization of metrics and user opinions.

The accurate evaluation of daylight conditions within a space, aided by daylight metrics, enhances the area's performance and improves energy efficiency. Designers can make informed decisions regarding parameters such as Window-to-Wall Ratio (WWR), window placement, orientation, and operational strategies. Such decisions can be made while minimizing disruptions and alterations to the existing plan, facilitating improvements.

Shafavi Moghadam and colleagues reviewed 58 field and laboratory studies between 2012 and 2020. They focused on evaluating users' visual comfort and predicting their preferences within indoor environments using various metrics. They noted that, according to the study results, a consensus on adequate and desirable illuminance thresholds has not yet been reached. Furthermore, due to the multifaceted nature of visual comfort and its reliance on various factors affecting user perception, a universally applicable glare metric for different conditions remains elusive (Shafavi, Zomorodian, Tahsildoost, & Javadi, 2020). Other studies have corroborated similar findings(Jakubiec & Reinhart, 2016), (Nezamdoost & Van Den Wymelenberg, 2017), (Tabadkani et al., 2021) emphasizing the absence of consensus on metrics and their associated thresholds. In another study assessing the efficacy of metrics, daylight performance and visual comfort were evaluated in four classrooms, all of which had achieved LEED Silver certification. This evaluation employed surveys and relevant metrics. The results revealed a strong correlation between student perceptions and the metrics sDA300/50% and UDI300-3000/50%. Additionally, metrics based on vertical brightness (sDGPexceed) demonstrated greater alignment with user opinions than metrics based on horizontal brightness (ASE). This implies the necessity of revisiting daylight and glare standards thresholds on a global scale, recognizing that the ability of individuals to adapt to varying light levels is influenced by cultural and climatic factors (Zomorodian & Tahsildoost, 2019). Another study on the same topic indicated that users' perceptions were related to point-in-time illuminance (EP), spatial daylight autonomy (sDA), and helpful daylight illuminance (UDI), respectively. Conversely, no significant correlation was found between grid-based glare metrics and users' responses. As per this research, UDI 300-3000/50% ≥ 75% and ASE1000, 250h ≤ 10% exhibited superior predictive capabilities in assessing available daylight and visual comfort among the annual metrics. This study was conducted across twenty architectural workshops, each receiving natural light through various strategies (e.g., skylights, light shelves, side windows) (Shafavi, Tahsildoost, & Zomorodian, 2020). In a study by Kang and Jakobi, point-in-time and long-term metrics in educational buildings within a tropical climate were examined based on user subjective evaluations. After analyzing the data, the researchers recommended instantaneous horizontal illuminance of 150 lx and vertical illuminance of 200 lx as lighting thresholds for classrooms to access daylight (Kong & Jakubiec, 2019). In 2017 research by Nezamdoost and Wymelenberg, a comparison was made between specific metrics (sDA and ASE) and user opinions. The lack of consideration for personal factors such as location and user activities were identified as a reason for the lack of correlation between these metrics and user evaluations. The researchers considered it impossible to employ these metrics universally for all conditions and spaces(Nezamdoost & Van Den Wymelenberg, 2017). **Table 1** provides an overview of recent research on the efficiency of daylight metrics in educational spaces, along with pertinent information. Like other studies focusing on the evaluation of metric efficiency (Shafavi, Tahsildoost, et al., 2020), (Shafavi Moghaddam, Zomorodian, & Tahsildoost, 2019),(Liu, Liu, Deng, & Hu, 2023),(Kong & Jakubiec, 2019), this research aims to assess the accuracy of these metrics in predicting daylight conditions of the space. Researchers in this field often recommend conducting further studies in spaces with varying daylight conditions and diverse climates. In summary, the findings from these studies reveal a lack of consensus regarding metrics for evaluating daylight and glare. This discrepancy may arise from using the same metrics indiscriminately without considering geographical location, usage, and the primary activities users undertake within the environment. Moreover, recommended metric thresholds may yield different outcomes in various applications and climates, given that these factors influence individuals' tolerance for light intensity.

Table 1
Performance of luminance and illuminance metrics according to the results of the reviewed studies.

Space type	REF.	Results	Objectives	Sim-software	Metrics	RES. Methods
Class	(Korsavi, Zomorodian, & Tahsildoost, 2016)	non-daylit areas or sun-lit areas defined by dynamic metrics would not necessarily cause visual discomfort,	testing students‟ evaluations on visual comfort through questionnaires in daylit and non-daylit areas in classrooms.		ASE, sDA	Questionnaire, Simulations, Field measurements.
Class	)Nezamdoost & Van Den Wymelenberg, 2017(	Identifying the reasons for weak correlation of users' evaluations with the results of the metrics.	Comparing the user's understanding of the daylit spaces and comparing it with the results of evaluating the metrics.	Radiance	sDA, ASE, cDA	Questionnaire, Simulations, Field measurements.
Class	(Fadaii Ardestani, Nasseri Mobaaraki, Ayatollahi, & Zomorrodian, 2018)	UDI 300-300(50%) and SVD are more appropriate for daylight and glare evaluations in the design process.	Comparing visual comfort conditions in different classes in order to choose suitable indicators.	Diva v.4 for Rhino	sDA, ASE, DF	Simulations, Field measurements.
Class	)Zomorodian & Tahsildoost, 2019(	A high correlation between users and Dynamic metrics (UDI300-3000 lux,50% sDA300,50%), Better performance of metrics based on vertical illuminance (sDGP) to Horizontal (ASE)	Examining pros and cons of the metrics, Rating of metrics, the amount of light and glare based on the ability to predict user satisfaction, Introduction of superior metrics.	Diva v.4 for Grasshopper	SDA, DA, UDI, ASE, DGPS	Questionnaire, simulations
Des-Studio	)Shafavi, Tahsildoost, et al., 2020(	A high correlation between users and annual metrics (UDI300-3000/50% ≥ 75% and Annual Sunlight Exposure ASE1000, 250h ≤ 10%) have better performance in predicting daylight availability and visual discomfort.	Evaluates the performance and robustness of some dynamic and static daylight and glare metrics by field studies in twenty architectural studios, daylit by different strategies.	Diva v.4 for Grasshopper	Ep, DF, UDI, sDA, ASE, sVD, DAv	Questionnaire, simulations
Class	)Liu et al., 2023(	The spatial daylight autonomy (sDA) at 450 lx for 50% of annual hours (sDA450/50%; a dynamic metric) and the proportion of area with an illuminance (Ep) > 300 lx (a static metric) were highly correlated with student evaluations.	Conducting correlation analysis of dynamic daylight metrics and subjective evaluation of students.	Rhino & Grasshopper.	DA, sDA, ASE, UDI, DGP, DF, EP	field surveys, Subjective surveyed, illu minance meas urements

The present research was conducted in the climate of Isfahan City, within architectural studio spaces, to evaluate daylight conditions and investigate the alignment of ordinary daylight and glare metrics with user satisfaction emphasis on their **activity type**.

3.Theoretical Framework

3.1. Research variables

In this research, the quantity of illumination, the uniformity of light distribution, and the presence of glare within a space were considered independent variables influencing user satisfaction and quality of the environment, with visual comfort as a dependent variable.

3.2. Daylight metrics

In this study's Evaluation of daylight condition, in addition to the commonly used metrics (as employed in most research), metrics from the LEED and EN 17037 standards, supported by the Climate plugin, were employed to encompass a broad range of validated evaluation metrics. The chosen metrics for assessing daylight quantity and glare are presented in **Table 2**.

Table 2
Daylight quantity, glare and uniformity metrics calculated using simulation in these studied.

Metrics	Type	Threshold	Ref.
ASE n lux,250 h	Dynamic	Percent of space which received direct radiation > 250 h during occupation time with > 1000 lx.	$LEED_{v4}$
Spatial Disturbing Glare(sDG)	Dynamic	The percentage of views across the regularly occupied floor area that experience disturbing or Intolerable Glare (DGP > 38%) for at least 5% of occupied hours. (%view with disturbing glare>5%time)	(Wienold & Christoffersen, 2006)
Useful Daylight illuminance (UDI)	Dynamic	Illuminance threshold: Failing (UDI_f): Less than 100 lux. Supplemental (UDI_s): Between 100 and 300 lux. Autonomous (UDI_a): Between 300 and 3000 lux. Excessive (UDI_e): More than 3000 lux.	Climatestudiodocs
Illuminance compliance level	Dynamic	**Minimum Illuminance** Minimum: 100 Lux /95 area≥50% time Medium: 300 Lux /95≥50% time High: 750 Lux /50≥50% time **Target Illuminance** Minimum: 300 Lux /50≥50% time Medium: 500 Lux /50≥50% time High: 750 Lux /50≥50% time	EN 17037
Spatial Daylight Autonomy (sDA)	Dynamic	sDA300lx,50%, No upper threshold, thus excessive values might cause visual discomfort due to glare.	$LEED_{v4}$
Mean Daylight Factor (DF)	Static	The average ratio of the daylight rate at any point inside the space to the amount of illumination available on the horizontal surface of the open space without obstacles in cloudy sky conditions, with minimum requirements typically ranging between 2% and 5%.	(Brotas & Wilson, 2007)
Illuminance Uniformity (Uo)	Static	Horizontal illuminance which is the ratio between minimum (E minimum) and the average (E average) illuminance intensity over a given task plane, 4%<DF<7% depending on the visual activity	BS-EN12665
%Area with (n lux ≤EP≥ n lux)	Static	daylighting penetration into the space as illuminance which is a physical measured in lux at a given point P of a surface (Ep). (Shafavi Moghaddam et al., 2019 200,300,…,1000).	(Mardaljevic, 2000)

4. Research Method

Given the applied nature of this research, the research methodology is quantitative, and its approach combines field surveys and modeling-simulation techniques. It progresses through the following six stages, as illustrated in Figure 1.

1. Reviewing existing research, focusing on investigating the effectiveness of daylight indicators in assessing visual comfort related to daylight quality in educational spaces.
2. For simulation, create 3D models for each of the six architectural studios in two architecture schools - Khorasgan and Tohid Khaneh that are different in architecture style (modern and historical building)- in Isfahan City.
3. User-completed questionnaires assessed students' satisfaction with visual comfort related to daylight in the selected studios.
4. Performing point-in-time and annual daylight simulations within the selected studios using the Climate Studio plugin in Rhino.
5. Comparing simulation results with user feedback through statistical tests to measure their correlation.
6. Identifying the metrics (both static and dynamic) that exhibited the highest correlation with user opinions according to their **main activity**.

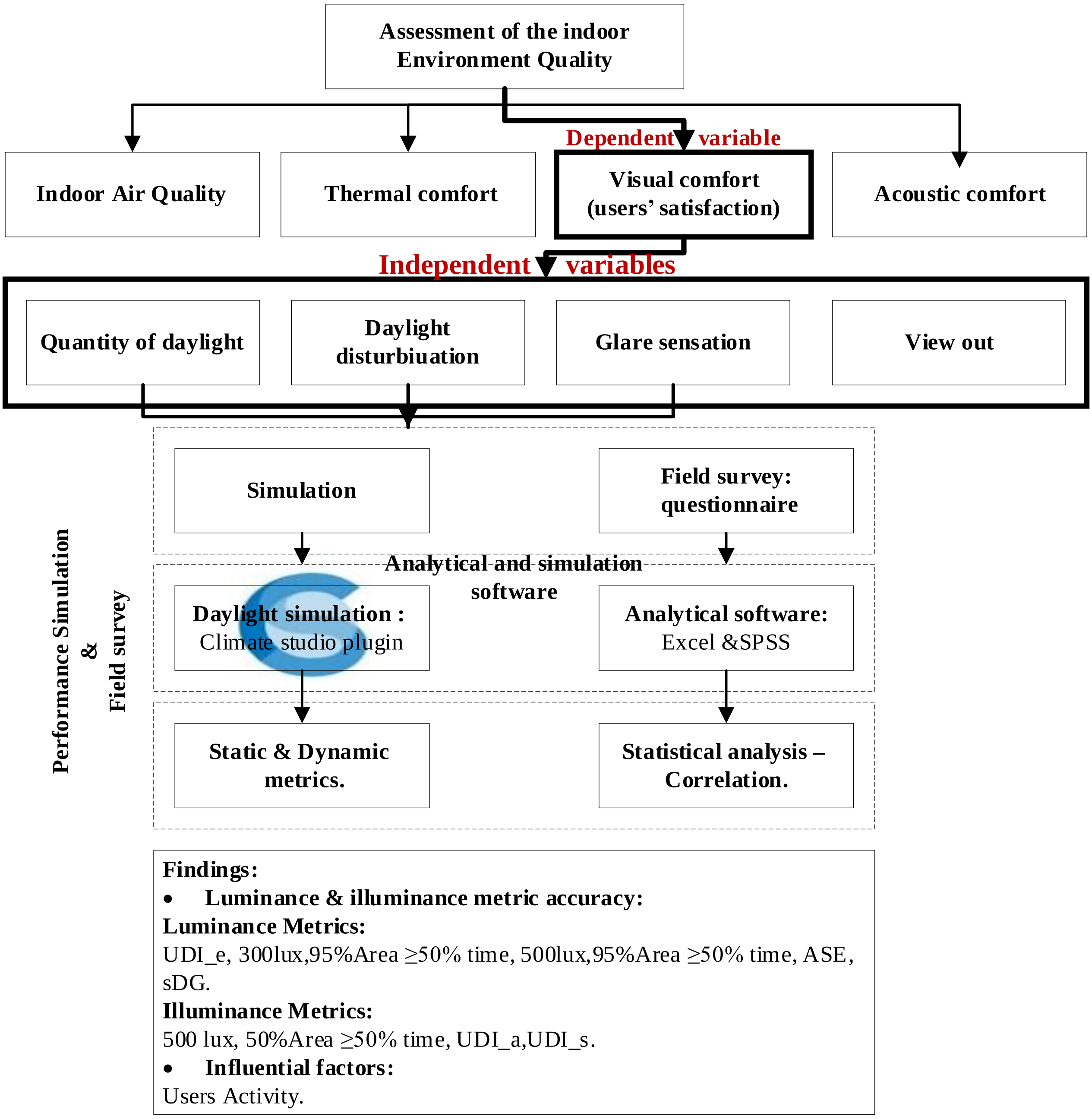


Fig. 1. Research workflow and conceptual model .

4.1. Field survey

The current project is situated in Isfahan city, with a geographical longitude of 51.862°E and a latitude of 32.751°N. Based on the Geiger coupon classification, it falls into the (Arid Steppe Cold)-BSk category. As per the climatic classification of cities in National Building Regulations-Topic 19, it falls within the category of medium thermal needs.

4.1.1. Time and survey conditions of research

Among the architecture faculties in Isfahan City, the design studios of the Faculty of Art and Architecture at Khorasgan were chosen as the sample population. This selection was based on architectural style of buildings, space characteristics, layout, orientation. The Faculty of Art Isfahan (Tohid Khaneh) was selected due to converting this faculty's traditional building into an educational facility. In traditional Iranian cities, it is common for architecture faculties to be housed in historical buildings. It is worth noting that both faculties have low levels of noise pollution due to the location of the Faculty of Architecture at Khorasgan (away from crowded areas) and the architectural layout of the Faculty of Art (a central courtyard without openings to the surroundings). The geographical locations of both faculties can be observed in Figures 2 and 3.

Fig. 3. Faculty of Art and Architecture of Khorasgan

Fig. 2. Faculty of Architecture, University of Art, Isfahan (Tohid-khane)

4.1.1.1. Faculty of art and architecture of khorasgan

Due to the similarity in dimensions between classroom spaces and standard architecture studios, three architectural design studios from this faculty were selected. One studio is located on the northwest side (Studio No. 1), and the other two are on the southeast side (Studio No. 15 and 16), featuring side-lit windows. Adjacent to the side window of Studio No. 15, there is a building with a protrusion of 5.20 meters, which was chosen for studying its shading effect and potential to create obstacles to direct sunlight.

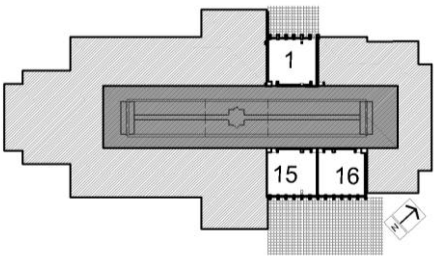
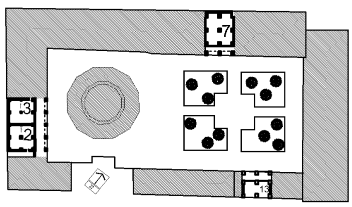
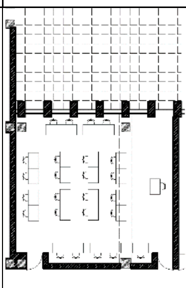
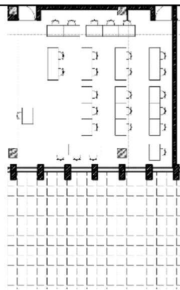
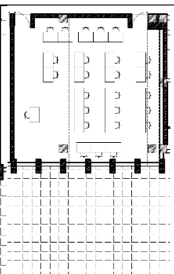
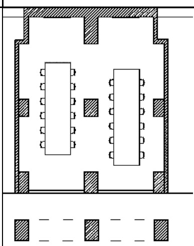
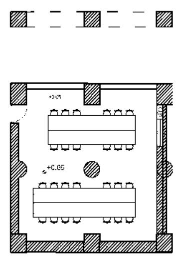
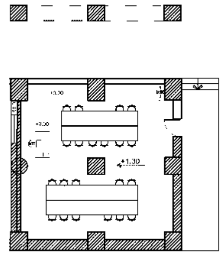
4.1.1.2. Faculty of architecture, university of art, isfahan (tohid-khane)

A valuable building with a rich historical past presents certain limitations for designers aiming to incorporate specific functional features while preserving authenticity. In some instances, these challenges have been successfully addressed, as seen in the design of Tohid Khane. The design studios within the Tohid khaneh building are situated on three sides (southwest, southeast and northeast), encircling the central courtyard. An effort was made to carefully select studios on each side, offering better and distinct conditions than others. Initial evaluations were conducted for each class. The southeast section of Studio 13 was omitted from the daylight evaluation due to its adverse impact on daylight analysis and dimensions (width: 5.50 meters).

These studios feature wooden profiles and translucent layers on their exterior facades. The presence of covered porches, spanning 3 meters around the central courtyard and in front of the studios, effectively limits the direct entry of excessive light into the spaces. The arrangement of the tables in both faculties' studios is such that students sit parallel to the side windows. **Table 3** provides the physical characteristics of the classes under study, while **Table 4** displays images and rendered radiance for each class.

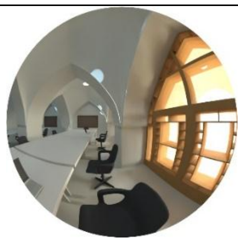
Table 3

Physical characteristics of the studied classes.

University	Khorasgan.Uni			Art-Uni		
Class. Num	Class.1	Class.15	Class.16	Class.7	Class.2	Class.3
						
Class. Plan						

Area		65.30	67.45	64.20	71.80	50.90	45.44
WWR		30	30	30	40	50	۴۰
Shading	Int.	Curtain fabric	Curtain fabric	Curtain fabric	-	-	-
	Ext.	0.45	0.45	0.45	3	3	۳
							

Table 4
Images and Radiance renderings of the investigated spaces.

Class.picture	Radiance.Render	
		Class.1
		Class.15
		Class.16
		Class.2

		Class.3
		Class.7

4.1.1.3. Reflection coefficient of interior surfaces and glazing visible light transmission

Calculating the reflection coefficient of interior surfaces for simulation purposes using a lux meter involved measuring the light intensity absorbed by the surfaces and then recording the reflected light intensity. The reflection coefficients of the interior surfaces and the transparency percentages of the glazing surface can be found in **Table 5.**

4.1.2. Field measurement - validation of simulation results

To ensure the accuracy of the simulation results, horizontal illuminance at a worktable height of 0.75 meters was measured using the Lutron LX-1108 lux meter at multiple points when users completed questionnaires in the classrooms of both faculties. **Table 6** describes the specifications of the photometric measuring device.

Table 5
Building material and optical properties in the cases

Surface properties		Art Uni.	Khorasgan Uni.
Window (single panel)	Visible Light Transmittance	0.70	0.75
	Win- Frame	0.30	0.20
External wall	brick	0.20	0.20
Internal wall	White- colored	0.70	0.7
Interior Ceiling	White- colored	0.60	0.60
Interior Floor	Wheat- colored	0.45	0.45

Table 6
Photometric measuring device

Model	**Lutron LX-1108 Light Meter**	
RANGES	5 ranges: 0.00/400.0/4,000/40,000/400,000 Lux	
Resolution	0.01 Lux to 100 Lux. 0.01 Ft-cd to 10 Ft-cd	

These measurements were subsequently compared with the simulation results at that particular time, as illustrated in Figure 4. This study involved field measurements taken with artificial lighting turned off, relying solely on daylight as the light source. The lux meter was calibrated before measurement to ensure the reliability and precision of the data collected during fieldwork. The correlation between the measured values and the simulation was 97%.

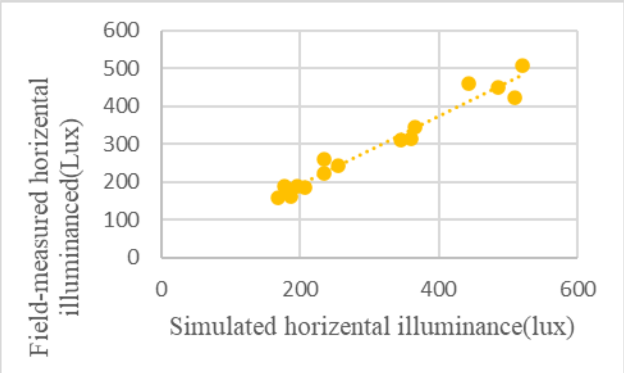


Fig. 4. Simulation vs. measurements illuminance values.

4.1.3. Distribution of the questionnaire

In this research, a questionnaire was distributed among the users to gain insight into their perception of natural light conditions within the space and assess their satisfaction or dissatisfaction. The questionnaire's face validity was established based on previous research (Shafavi, Tahsildoost, et al., 2020) and was prepared accordingly. Subsequently, experts reviewed the questionnaire in form and content, which was distributed to the targeted community. The experts involved in this research were guiding and consulting professors who received the questionnaire and provided their opinions regarding the questionnaire's questions. Some modifications were made to the questionnaire in consultation with them. The questionnaire's first section gathered general information about the respondents and their activities within the study area. The second part contained questions about evaluating daylight conditions and overall user satisfaction with the space. The questions from the second part can be found in **Table 7**. The questionnaires were distributed around 11 AM, with the lights off and curtains drawn aside, allowing users to respond under natural lighting conditions.The total number of art students from both universities was 205, with 111 primarily using computers for their activities in the evaluated spaces. According to the KMO and Bartlett's Test, the sample size adequacy index was 0.799, which suggests that 205 is sufficient for this research at a 99% confidence level. After collecting data from the questionnaire, the data were entered into SPSS software, and Cronbach's alpha coefficient was calculated, as shown in **Table 8**.

Table 8
Cronbach's alpha coefficient

Structure	Cronbach's alpha
Satisfaction with the amount and distribution of natural light	0.749
sense of glare and source of glare	0.792
Satisfaction with the window view	0.795
Overall satisfaction	0.805

As is evident from the table above, all Cronbach's alpha coefficients of the research variables are more significant than 0.7 and range from 0.749 to 0.805, which indicates that the reliability of the research questions has been accepted with a high level of confidence. The questionnaire was distributed in December and January and select sunny days for respondents to provide feedback.

Table 7
Questionnaire questions distributed among architecture students

Satisfied with the amount of daylight	
A. Work on the desk:	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
B. Work with computer:	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
C. Blackboard/whiteboard observation	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
D. Having enough focus:	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
E. How satisfied are you with the uniformity of daylight in this classroom?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
F. How do you evaluate amount of daylight in this time?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
G. In general, How satisfied are you with the amount of daylight in the classroom?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
Glaring And its source	
How disturbing is the glaring on …..?	
H. On the desk	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
I. Computer	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
J. How disturbing is direct sunlight in this classroom?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
K. How disturbing is the light contrast in this classroom?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
Thermal satisfaction	
L. How do you evaluate thermal condition/comfort in this class?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied
General satisfaction	
M. In general, how satisfied are you in this classroom?	Totally dissatisfied 1|2|3|4|5|6 Totally satisfied

Table 9
Percentage of **paper and computer work' respondent** in different studios toward: daylight quantity, daylight uniformity and Discomfort glare, overall satisfaction.

	A	B	C	D	E	F	G	H	I	J	K	L	M
class 1.2JAN11.00	30 %	56 %	61%	63%	32%	32%	42%	80%	87%	87%	66%	45%	69%
class 3.28Dec-11.00	45 %	82 %	53%	68%	48%	45%	55%	82%	84%	81%	60%	50%	71%
class 7.26Dec-11.30	72 %	80 %	52%	69%	65%	70%	78%	74%	69%	71%	59%	65%	78%
class 16 .4Jan-11.00	69 %	35 %	30%	63%	65%	65%	75%	50%	40%	41%	38%	78%	63%
class 15. 31Dec-11.30	59 %	65 %	51%	68%	61%	68%	65%	65%	61%	56%	56%	73%	68%
class 2.21Dec-11.00	32 %	82 %	75%	72%	38%	40%	45%	63%	69%	73%	64%	43%	82%

Table 10
Percentage of **paper work' respondent** in different studios toward: daylight quantity, daylight uniformity and Discomfort glare, overall satisfaction.

	A	B	C	D	E	F	G	H	I	J	K	L	M
class 2 -28Dec-11.30	45%	-	32%	68%	32%	43%	64%	86%	-	83%	56%	35%	63%
class 15 -2Jan-11.00	75%	-	42%	68%	78%	72%	79%	58%	-	65%	64%	74%	75%
class 1 -31Dec-11.00	32%	-	25%	60%	38%	35%	51%	93%	-	87%	35%	45%	56%
class 16 -31Dec-11.30	65%	-	49%	72%	73%	76%	79%	55%	-	53%	60%	73%	64%
class 3 -20Dec-11.00	43%	-	35%	66%	48%	58%	62%	74%	-	74%	52%	56%	62%
class 7 -28Dec-11.00	68%	-	50%	65%	67%	62%	73%	69%	--	76%	55%	62%	73%

User opinions regarding their satisfaction with daylight quantity and distribution, annoyance from direct sunlight, extreme contrast, and overall evaluation of space conditions are presented in **Tables 9 and 10**, categorized by activity type (mainly computer-based or mainly paper-based). Based on the review of tables, it was determined that the average users' evaluations in response to the questions about the amount and distribution of natural light are above 50% in all cases in studios No. 7 and 15. In studio No. 16, due to the intensity of the light, users are not satisfied with viewing the whiteboard, working with the computer, and concentrating. In studio No. 1, students' satisfaction with the amount of light inside the classroom, for working on the desk, and the uniformity of light distribution is low (30%). These tables were interpreted, and explanations have already been given in other tables. This could be attributed to the orientation of the light-receiving front (northwest front). In the glare section, students' satisfaction with the absence of annoying glare averages about 40%. While in other studios, users' satisfaction with the absence of annoying glare is relatively high (50%<X). In class No. 16, due to the intensity of the light entering the space, especially in the summer, users' satisfaction with the ambient temperature is higher than in other studios. Despite the students' dissatisfaction in some areas, their overall satisfaction with the overall condition of the studios is above 50%. Therefore, it may be stated that a set of conditions, by ensuring minimal satisfaction in all areas, affects the level of satisfaction of individuals with the overall condition of the space or that dissatisfaction in one area will not be a reason for their overall dissatisfaction with the conditions.

4.2. Simulation

Rhino7 software was selected to create three-dimensional models of the designated studios. Point-in-time and annual daylight assessments were conducted using the Climate Studio plugin in Rhino to calculate energy consumption. Data analysis was performed using SPSS and Excel software, with the Pearson test used to determine correlations and significant relationships between variables. The significance level for this research was set at 0.05.

4.2.1. Energy simulation

Energy consumption in buildings is significant, as buildings are among the highest energy consumers globally. Approximately 30% to 40% of the world's energy consumption is attributed to building operations. Educational buildings, in particular, account for a significant portion of this energy usage, representing approximately 15% of the total energy consumption in the non-residential sector(Khani, Khakzand, & Faizi, 2022). About 14% of the total energy consumption within educational buildings can be attributed to lighting energy(Fadaii Ardestani et al., 2018). Therefore, the efficient utilization of daylight, one of the most cost-effective energy investments, can substantially reduce energy consumption. However, excessive daylight penetration through transparent surfaces not only prompts users to draw curtains and use artificial lighting despite available natural light but also increases cooling loads (due to elevated indoor temperatures) and overall energy consumption within the building. Therefore, by identifying valid and accurate indices for evaluating daylight conditions suitable for different climates and building types, it is possible to assess the lighting conditions within a space and achieve significant energy savings during the design phase and even during operation by providing corrective solutions. In the energy simulation process by climate studio for space utilization (design studios), a target illuminance level of 500 lux (lx) was considered for the work plane. If daylight levels fall below this target, the electric lighting system activates (dimming type: stepped), resulting in recorded electric energy consumption. **Table 11** outlines the energy consumption for the entire space of each class and separately for various sections. In the Faculty of Khorasgan Architecture, southeast classrooms (classes 15 and 16), annoying glare compels users to draw curtains despite adequate daylight during occupancy, reducing illuminance and necessitating electric lighting. In class 1 of the same faculty, considering the space's area, the northwest-facing translucent layers do not provide sufficient daylight. In the Tohid Khane studios, due to the high domed ceilings and corridors in front of the classes, glare only occurs near the openings and is limited. Consequently, by offering appropriate solutions tailored to the building's characteristics, energy efficiency in lighting can be improved.

4.2.2. Daylight simulation

Illuminance data obtained from the simulation related to the moment of questionnaire distribution in the design studios under study, categorized by the type of activity, are presented in **Tables 12 and 13**. It should be noted that the studios were evaluated on several different days, so the instantaneous lighting simulation for the aforementioned classes was also performed over several days, corresponding to the actual conditions experienced by the users during the response. **Table 14** provides annual data about each studio, indicating the percentage of space that receives daylight during occupancy.

Table 11
The amount of energy consumption for each design studio.

Num. class	Area M^2	EUI Kwh/m^2	Energy Use				
			Energy use kwh	Heating kwh	Cooling kwh	Light kwh	Equip
15	87.50	89	7736	550	1164	1780	4243
16	83.60	85	7118	105	1361	1610	4052
1	87.10	102	8981	1080	1065	2571	4264
7	88.40	86	7826	3668	1250	841	2067
3	56.90	131	9128	5757	941	795	1635
2	70.10	138	9679	6210	927	906	1635

Table 12
The percentage of daylit area based on static metrics in different classes.

NUM.Classes & Dates		<50	50< <100	100< <150	150< <200	200< <250	250< <300	300< <350	350< <400	400< <450	450< <500	500< <1000	>1000	U0	Mean DF	Uniformity
ART	cl 2- 21Dec-11.00	0.00	16.41	62.50	20.31	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.27	0.60	60.50
	cl 3 -28Dec-11.00	0.00	8.93	74.11	16.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.44	0.43	50.12
	cl 7 -26Dec-11.30	0.00	0.00	17.16	33.14	11.24	17.75	10.65	3.55	3.55	1.78	1.18	0.00	43.59	0.48	37.98
KHO	cl 1- 2JAN-11.00	9.52	52.98	19.05	11.31	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.43	0.76	10.76
	cl 15 -31Dec-11.30	0.00	2.79	25.70	22.91	15.64	7.26	6.15	6.15	4.47	1.68	6.15	1.12	28.29	0.92	32.61
	cl16 -4Jan-11.00	0.00	0.00	0.00	0.00	0.56	5.03	12.85	8.94	10.06	6.15	40.22	16.20	13.68	1.22	30.22

Table 13
The percentage of daylit area based on static metrics in different classes.

NUM.Classes & Dates		<50	50< <100	100< <150	150< <200	200< <250	250< <300	300< <350	350< <400	400< <450	450< <500	500< <1000	>1000	U0	Mean DF	Uniformity
ART	class 2 -28Dec-11.30	0.00	0.00	2.79	20.67	17.32	11.17	11.17	7.82	3.35	6.70	15.08	3.91	58.11	0.60	60.50
	class 3 -20Dec-11.00	13.10	47.62	20.24	11.90	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.40	0.43	50.12
	class 7 -28Dec-11.00	0.00	0.00	0.00	5.03	16.20	11.73	9.50	8.94	7.26	5.03	27.93	8.38	39.86	0.48	37.98
KHO	class 1 -31Dec-11.00	0.00	0.00	20.31	43.75	28.91	5.47	1.56	0.00	0.00	0.00	0.00	0.00	35.30	0.76	10.76
	class 15 -2Jan-11.00	0.00	10.71	68.75	20.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.13	0.92	32.61
	class 16 -31Dec-11.30	0.00	0.00	10.65	30.77	13.02	4.73	18.34	8.28	4.73	2.37	7.10	0.00	22.41	1.22	30.22

Table 14
The percentage daylit area based on dynamic metrics in different classes and orientation.

NUM. Cl	UDI_f	UDI_s	UDI_a	Min DF	Mean DF	Median DF	Uniform.	300LUX, 50%	500LUX, 50%	750LUX, 50%	100LUX 95%	300LUX, 95%	500LUX, 95%	sDA	UDI_e	ASE	sDG
2	6.56	59.3	33.8	0.37	0.60	0.58	60.5	26.4	0.00	0.00	70.3	0.00	0.00	24.9	0.34	0.00	0.00
3	11.4	72.2	16.1	0.22	0.43	0.40	50.1	75.	0.00	0.00	53.0	0.00	0.00	0.68	0.28	0.00	0.00
7	10.7	52.7	36	0.18	0.48	0.39	37.9	23	65.5	0.50	53.2	3.61	0.00	23.8	0.67	0.00	1.40
1	17.1	54.3	28.6	0.08	0.76	0.53	10.7	25.6	1.64	0.00	71.8	0.00	0.00	34.4	0.00	0.00	0.00
15	4.1	30.7	62	0.30	0.92	0.64	32.6	50.1	27.6	13.1	77.4	22.9	7.90	61.8	2.24	4.05	7.70
16	3.4	20.2	74	0.37	1.22	0.83	30.2	60.4	36.3	18.3	70.1	33.8	10.3	66.2	2.45	4.60	10.3

5. Results and Discussion

5.1. Correlation of illuminance and luminance metrics and user evaluation

This section will explore the relationship between static and dynamic metrics, calculated using data from point-in-time and annual simulations and user evaluations. This exploration aims to determine which metrics' predictions align more closely with user perceptions.

5.1.1. Point in time simulation

To ascertain the illuminance range perceived by users, which serves as the criterion for their responses, the correlation between their responses and various questions (related to the amount of daylight, uniformity of daylight, disturbing direct sunlight and contrast, thermal conditions, and overall satisfaction) was investigated. This investigation was conducted concerning the type of activity in architectural studios, distinguishing between those primarily engaged in computer-based work and those predominantly involved in paperwork. It is important to note that in the Faculty of Art, Isfahan, the class space is divided into two parts due to the placement of columns in the center. Since students utilize both spaces for seating and the whiteboard is situated on one side of this space, students on the opposite side temporarily relocate when they need to see the board. Consequently, evaluating suitable lighting for board visibility from each student's location during class is not accurately considered. As a result, the question regarding student satisfaction with board visibility was excluded. Subsequently, the correlation coefficients between user opinions and static metrics by activity type are presented. **Table 15** displays the correlation coefficients of static metrics and qualitative evaluations for users primarily engaged in paperwork in the studios. A noteworthy high and significant correlation exists between satisfaction with the amount of light on the worktable and the illuminance level in the range of 250 to 500 lux for students primarily engaged in paperwork. In a similar study, not accounting for activity type, the highest correlation between user satisfaction and space illuminance falls within the range of 100 to 300 lux (Shafavi Moghaddam et al., 2019). Furthermore, a high and significant correlation is observed between user satisfaction and illuminance levels ranging from 250 to 1000 lux. Notably, there is no significant relationship between user satisfaction and illuminance uniformity metrics. The results indicate that users primarily engaged in paperwork report experiencing discomforting glare on their worktables when the illuminance levels exceed 500 lux.

Table 15
Correlation coefficients of daylight metrics and paper-based work of users.

Thresholds of metric	A	D	E	F	H	J	K	L	M
<50	-0.655	-0.805	-0.457	-0.692	0.667	0.546	-0.910*	-0.396	-0.658
50< <100	-0.746	-0.838*	-0.513	-0.703	0.692	0.566	-0.947**	-0.415	-0.727
100< <150	-0.590	-0.323	-0.505	-0.321	0.378	0.359	-0.318	-0.370	-0.428
150< <200	-0.043	-0.066	-0.415	-0.347	0.358	0.536	0.191	-0.575	0.233
200< <250	0.302	0.447	-0.024	0.020	-0.059	-0.055	0.472	-0.190	0.277
250< <300	0.822*	0.829*	0.739	0.765	-0.801	-0.798	0.808	0.666	0.618
300< <350	0.875*	0.355	0.793	0.651	-0.660	-0.438	0.542	0.654	0.847
350< <400	0.930**	0.590	0.939**	0.847*	-0.866	-0.753	0.644	0.860	0.765
400< <450	0.794*	0.666	0.842*	0.818*	-0.832	-0.823*	0.563	0.802	0.537
450< <500	0.885*	0.637	0.920**	0.846*	-0.879	-0.808*	0.710	0.879*	0.722
500< <1000	0.719	0.770	0.812*	0.836*	-0.860*	-0.938**	0.602	0.821*	0.409
>1000	0.564	0.771	0.682	0.752	-0.778*	-0.926**	0.535	0.729	0.227
DF average	0.384	0.540	0.513	0.491	-0.537	-0.721	0.294	0.550	0.055
Uniformity	0.048	0.410	-0.240	0.052	-0.017	0.054	0.504	-0.296	0.190
U0	-0.607	-0.257	-0.686	-0.462	0.517	0.510	-0.253	-0.629	-0.415
*Significant correlation sig < 0.05 and ** significant correlation sig < 0.01									

Table 16 presents the correlation coefficients of static metrics and qualitative evaluations for users primarily engaged in computer-based and paperwork activities in the design studio.

Table 16
Correlation coefficients of daylight metrics and computer & paper-based work of users.

Thresholds of metric	A	B	D	E	F	H	I	J	K	L	M
<50	-0.568	-0/270	-0.588	-0.666	-0.640	0.452	0.537	0.537	0.430	-0.461	-0.171
50< <100	-0.791	-0/088	-0.385	-0.863*	-0.833*	0.484	0.646	0.668	0.588	-0.687	0.020
100< <150	-0.570	0/766	0.678	-0.483	-0.508	0.444	0.563	0.558	0.556	-0.678	0.513
150< <200	0.134	0.815*	0.753	0.138	0.257	0.443	0.361	0.369	0.573	-0.136	0.725
200< <250	0.335	0/077	0.060	0.336	0.487	0.150	0.019	-0.065	0.184	0.379	-0.007
250< <300	0.812*	0/098	0.161	0.753	0.811*	-0.082	-0.310	-0.295	-0.203	0.580	0.166
300< <350	0.938**	-0/507	-0.280	0.898*	0.878*	-0.612	-0.810*	-0.799*	-0.797*	0.899*	-0.357
350< <400	0.810*	-0/690	-0.385	0.831*	0.817*	-0.770	-0.913*	-0.96**	-0.899*	0.971**	-0.619
400< <450	0.793*	-0/749	-0.458	0.792	0.745	-0.797	-0.930**	-0.94**	-0.957**	0.919**	-0.620
450< <500	0.734*	-0/782	-0.509	0.719	0.648	-0.798*	-0.913*	-0.906*	-0.97 **	0.842*	-0.616
500< <1000	0.541	-0/849*	-0.584	0.538	0.444	-0.813*	-0.869*	-0.862*	-0.97**	0.712	-0.687
>1000	0.499	-0/844*	-0.594	0.489	0.385	-0.794*	-0.839*	-0.823*	-0.95**	0.657	-0.668
Mean DF	0.322	-0/927**	-0.660	0.341	0.328	-0.784	-0.775	-0.806*	-0.771	0.664	-0.753
Uniformity	-0.071	0/659	0.852*	0.023	0.007	-0.109	-0.030	0.030	0.119	-0.236	0.614
U_0	-0.517	0/871*	0.680	-0.485	-0.510	0.634	0.709	0.734	0.680	-0.758	0.662
*Significant correlation sig < 0.05 and ** significant correlation sig < 0.01											

The findings reveal that illuminance levels in the range of 250 to 500 lux significantly correlate with user satisfaction regarding the amount of light for their desks, which closely aligns with the daylight threshold for paperwork users'. Conversely, a positive correlation exists between user satisfaction and illuminance levels in **computer users' 150 to 200 lux range.** The introduction of backlit screens in architecture classes from the first semester has significantly impacted visual comfort related to lighting, as screen users often require consistent illumination. Consequently, it is imperative to establish lighting requirements based on the specific user activity. It is worth noting that variations in user expectations for light intensity in different spaces necessitate the adaptation of lighting standards according to space use and geographical location, as highlighted in the research of Korsavi and others(Korsavi et al., 2016). Regarding responses to glare-related questions and static indicators, users engaged in mainly computerwork activities report experiencing discomforting glare on laptop screens when illuminance levels exceed 300 lux. Many studies have traditionally focused on evaluating glare at a single point, yet the duration of a user's exposure to glare influences their perception. Therefore, it is advisable to incorporate the duration of exposure to glare into glare indicators. The investigation into glare indicators and their correlation with user opinions suggests that factors influencing the perception of discomforting glare should be weighted based on geographical location, space use, activity type, and personal characteristics of space users to determine each factor's impact on glare perception. The results further demonstrate a strong correlation between user satisfaction with the amount of daylight when working with a computer and the U_0 metric, which assesses the uniformity of light distribution. However, no such correlation exists between user satisfaction and the uniformity index in other instances.

For users primarily engaged in computer-based work, there is a positive correlation between satisfaction with ambient temperature and point-in-time illuminance levels within the range of 300-500 lux. In contrast, this correlation is observed within the range of 350 to 1000 lux for those primarily involved in paperwork. This disparity in the maximum threshold may be attributed to the heat generated by laptop components in the classroom. The correlation between paperwork users' satisfaction with ambient temperature and this specific illuminance range may be linked to the desire of students to expose their skin to radiation within that threshold, which they find pleasant. However, this level of correlation may not hold for these users in different settings or climates, as individual tolerance varies across different environments.

Therefore, a comprehensive investigation of the correlation between these indicators and user satisfaction regarding ambient temperature during field research conducted in various climates is necessary to gain a comprehensive understanding. Considering that the research was conducted during the winter (December and January) with the heating system operating in all classroom spaces, accurately determining the correlation between user satisfaction with ambient temperature and the amount of lux received is challenging. The presence of the heating system precludes predicting the effect of ambient lighting on user satisfaction with ambient temperature. Consequently, it is advisable to conduct evaluations during multiple periods in various months.

In The following step will explore the degree of correlation between dynamic indicators and the satisfaction of students engaged in computer-based and paperwork classroom activities.

5.1.1. Annual Simulation

This section evaluates the relationship between dynamic daylight metrics and user opinions to ascertain which metrics more accurately predict user satisfaction.

Table 17
Correlation coefficients of dynamic metrics and subjective evaluation of users

Questions		UDI_f	UDI_s	UDI_a	500, 50%	750, 50%	100, 95%	300, 95%	500, 95%	sDA	UDI_e	ASE	sDG
Daylight	**A**	-0.762	-0.766	0.812*	0.825*	0.696	0.131	0.739	0.681	0.656	0.800	0.679	0.754
	B	0.739	0.946**	-0.958**	-0.448	-0.951**	-0.439	-0.966**	-0.937**	-0.871*	-0.915**	-0.911*	-0.954*
	D	-0.784	-0.110	0.264	0.274	0.218	-0.134	0.230	0.217	0.019	0.364	0.227	0.242
	E	-0.775	-0.648	0.711	0.773	0.679	-0.020	0.713	0.672	0.516	0.812	0.682	0.736
	F	-0.754*	-0.520	0.597	0.713	0.616	-0.194	0.651	0.606	0.358	0.742	0.608	0.668
	G	-0.623	-0.601	0.636	0.854*	0.624	-0.169	0.668	0.611	0.445	0.747	0.614	0.689
Glare	**H**	0.903**	0.847*	-0.908**	-0.523	-0.914**	-0.277	-0.630	-0.905**	-0.742	-0.952**	-0.894**	-0.931**
	I	0.829	0.903**	-0.941**	-0.526	-0.924**	-0.334	-0.945**	-0.909**	-0.804*	-0.926**	-0.886**	-0.937**
	J	0.843*	0.868*	-0.912**	-0.468	-0.954**	-0.291	-0.966**	-0.944**	-0.736	-0.961**	-0.928**	-0.962**
	K	-0.264	0.316	-0.208	0.023	-0.305	-0.077	-0.317	-0.280	-0.279	-0.114	-0.221	-0.273
Satis.	**M**	-0.259	0.153	-0.071	0.493	-0.255	-0.266	-0.224	-0.253	-0.188	-0.044	-0.215	-0.185
*Significant correlation sig < 0.05 and ** significant correlation sig < 0.01													

Table 17 displays the results of the correlation coefficients of user quality evaluation with annual metrics. To account for the unique characteristics of dynamic metrics, students who had spent at least one term in the space under investigation were selected to complete the questionnaire. The UDI_s metric significantly correlates with user satisfaction regarding the amount of daylight available for computer work and user responses to glare-related questions. Computer users' express satisfaction with the amount of daylight within the range considered for the UDIs. Moreover, given the computer's backlight, this illumination level does not induce

discomfort in the observer's eyes. Users' satisfaction with working at their desks exhibits a noteworthy positive correlation with the UDIa metric. The metric (500lux, 50% Area ≥50% Time) exhibits a high and significant correlation with daylight satisfaction in this class. Glare occurrence is one of the most significant classroom issues arising from inappropriate window design and orientation. Consequently, users often prefer drawing curtains and relying on artificial classroom lighting rather than embracing natural daylight. A significant negative correlation emerges between the UDIe-ASE-sDG metrics and user responses concerning the adequacy of daylight for computer and work desk. Similarly, a significant negative correlation exists between the UDIe- ASE- sDG metrics, 500lux, 95% Area ≥50% time with the level of student satisfaction related to the absence of disturbing glare across various sections. According to the findings, no correlation emerges between the response to "The level of user satisfaction with the quality of the indoor environment" and any annual daylight metrics. This underscores that overall satisfaction hinges on various visual aspects, with sufficient daylight devoid of disturbing glare being just one of them, which aligns with the expectations.

In light of the insights above, it can be concluded that users' satisfaction is contingent on various visual aspects, each affecting their overall satisfaction and perception differently.

6. Conclusion

Based on the information provided, it can be affirmed that user satisfaction is contingent on various facets of visual aspects, influencing their spatial perception. Given the intricate nature of visual comfort and its reliance on many factors affecting user perceptions, none of the metrics can definitively gauge space conditions and apply universally. Nevertheless, specific metrics correlate more strongly with user opinions regarding spatial satisfaction than others. The lighting requirements in architectural studios differ significantly based on the specific activities in which users are engaged, such as computer work or paperwork. This variation has a considerable impact on user satisfaction. Critical factors include the intensity of available light and the degree of glare experienced. It is imperative to acknowledge these differences and appropriately adjust lighting standards, as these factors directly influence overall user satisfaction.

The present study conducted a comparative analysis between daylight metrics and user evaluations to scrutinize the metrics' reliability in predicting user satisfaction within two distinct user activities: primarily involving computers and predominantly paper-based tasks.

To facilitate this inquiry, commonly accepted and widely utilized metrics were employed to assess daylighting conditions within six architectural design studios. The outcomes reveal that among the static metrics, the point-in-time illuminance within the range of Ep=250-500lx, in both activity scenarios, exhibits a significant positive correlation with student satisfaction at their desks. Additionally, a positive correlation exists between the range of Ep=150-200lx and user satisfaction levels when working with computers. Therefore, classrooms that receive northern and eastern daylight are more suitable for users who are primarily involving computers.

As per the findings, concerning responses to questions about glare and static metrics, users primarily engaged with laptops report experiencing bothersome glare on their laptop screens when exposed to illuminance levels exceeding 300 lux. Conversely, users engaged in paper-based tasks report encountering annoying glare on their work desks when subjected to illuminance levels exceeding 500 lux. Among the dynamic metrics, the UDI_s metric displays a significant positive correlation with user satisfaction regarding the amount of daylight available for computer work and user responses regarding non-annoying glare. The influence of computer backlighting on user behavior in the workspace suggests that such individuals prefer exposure to less daylight than the standard (i.e., the amount of daylight required for desk activities, 500 lux).

Therefore, further research should be conducted on computer users to explore the optimal amount of daylight necessary for their activities within broader contexts. A noteworthy observation is the significant positive correlation between user satisfaction when working at a desk and the daylight metric UDIa. Furthermore, the metric 500lux, 50%Area ≥50% time exhibits a strong and significant correlation with satisfaction derived from the amount of daylight in the studios. Conversely, a significant negative correlation emerges between the metrics UDIe, ASE, and sDG and user responses concerning the absence of disturbing glare in the studios.

It is essential to highlight that a porch in front of the Tohid Khane Faculty classrooms substantially reduces direct sunlight penetration into the space, effectively mitigating significant glare issues. Hence, it is imperative to assess the accuracy of the results derived from the correlation of these metrics with user satisfaction across a broader spectrum of samples.

In light of those above, it is evident that there exists no direct correlation between overall user satisfaction with classroom conditions and the dynamic or static daylight evaluation metrics. This underscores the fact that overall satisfaction hinges on many factors, one of which is the provision of sufficient daylight without causing glare-related discomfort.

In the Khorasgan Faculty, studios on the southeast side contend with irritating glare issues. To establish optimal visual comfort conditions for users and make judicious use of daylight, it becomes essential to undertake necessary preparations, such as implementing appropriate lighting systems or designing light shelves adjacent to the windows.

In the Faculty of Art, the architectural constraints of the building, rooted in its traditional design, offer opportunities for enhancing conditions by modifying window frames or increasing the reflectance coefficient of surfaces.

Substantial improvements in natural lighting can be achieved by evaluating existing building in terms of natural lighting conditions and employing pertinent metrics tailored to each region's climate, followed by the proposal of suitable corrective measures for each space. A salient benefit of this approach is improving the performance of space in terms of energy, receiving optimal daylight and visual comfort in architectural studio spaces.

Suggestions and Limitations

- ✓ Conducting similar research considering the **type of user activity**.
- ✓ Considering **adaptability and tolerance of conditions** by users in **different climates** to determine the threshold of metrics and introduce glare metrics compatible with the climate.
- ✓ Evaluating the **non-visual effects of daylight** on user satisfaction in space and investigating
- ✓ the reliability of the considered metrics for this field.
- ✓ Investigating the relationship between annoying glare and satisfaction with ambient temperature.
- ✓ Investigating the effect of the **duration of user presence** for feeling annoying glare.

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