Exploring the Impact of Spatial Factors on Circadian Daylight Distribution

Authors
Neda Ghaeili, Julian wang
Email
nxg51@psu.edu
Organization
Department of Architectural Engineering Pennsylvania State University, State College, USA

INTRODUCTION

The impact of circadian light on human well-being is increasingly recognized, with studies revealing its effects on mental health, cancer susceptibility, cognitive performance, and physical activity. As indoor environments dominate modern lifestyles, understanding factors influencing circadian light exposure becomes paramount. Ghaeili Ardabili et al. (2023) identify key nodes—daylight source, window characteristics, interior spaces, and occupant posture—that affect indoor circadian light. While factors like window optical properties and morphology are critical, their interplay with variables such as window-to-wall ratio, orientation, and shading systems further shapes circadian light transmission. Similarly, interior architecture and occupant gaze direction significantly influence circadian light exposure levels. This study investigates the correlation between gaze direction, distance from windows, interior surface reflectance, and window transmittance using simulated room models, shedding light on optimizing indoor environments for human well-being.

OBJECTIVE

This study analyzed how windows' visible transmittance, interior surface reflectance, and occupant position affect circadian light exposure indoors by using simulations conducted with the LARK Plugin for Grasshopper.

METHODOLOGY

Ten windows with varying Tvis values were chosen from the International Glazing Data Base (IGDB) to cover intervals within the 0 to 1 Tvis range (FIG1). Interior surface reflectance for ceilings, walls, and floors adhered to ASHRAE recommendations. Analysis was conducted using a 7*7*3 m3 box model with a 30% window-to-wall ratio (WWR) in ASHRAE climate zone 4 during the noon fall equinox. Simulations utilized a six-by-six grid positioned 0.5m from room walls to assess four gaze directions—perpendicular, parallel (facing west and east walls), and away from the window—coded as S, W, E, and N, respectively (FIG2).

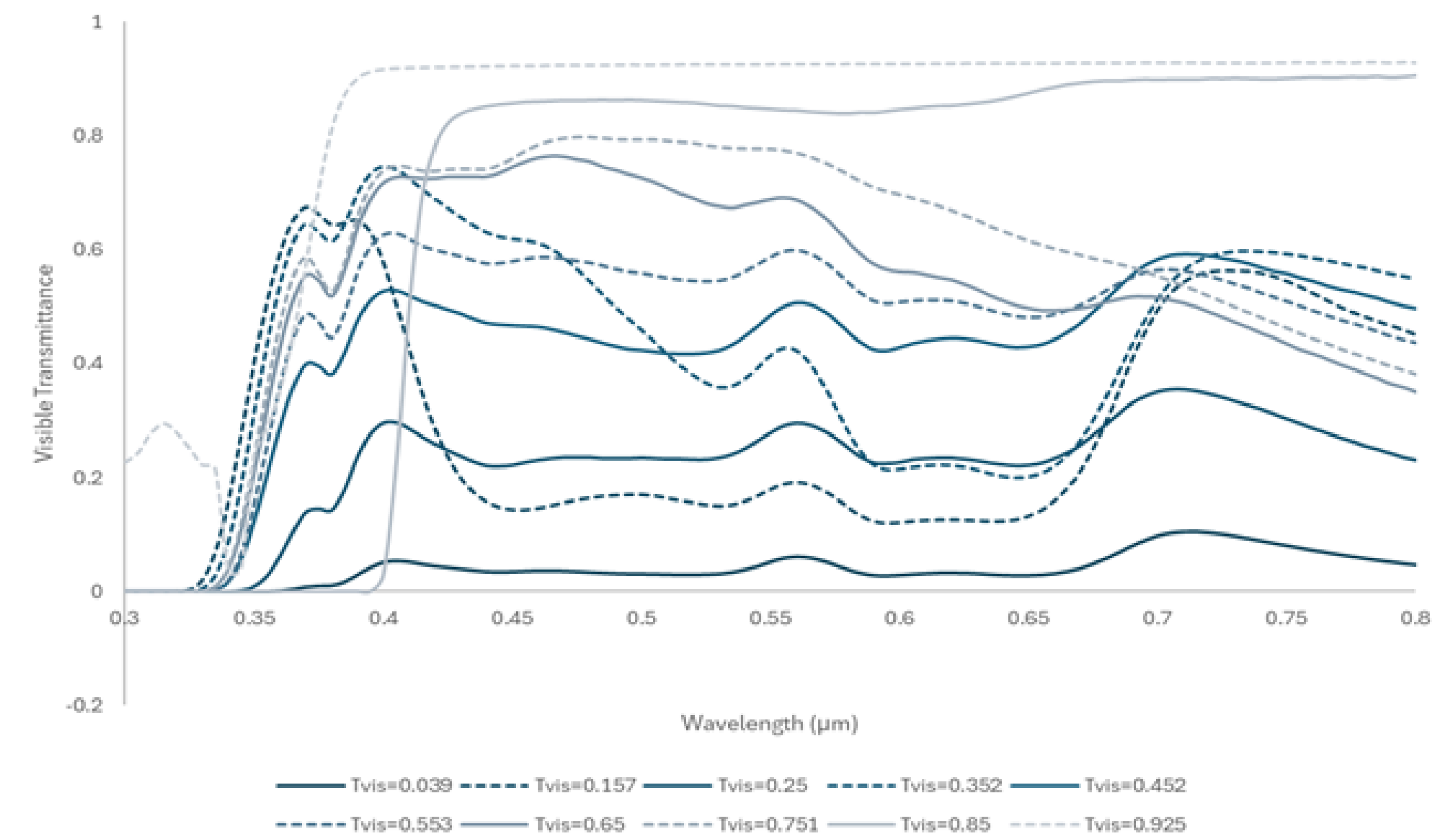


FIG1. SPECTRAL TRANSMITTANCE OF THE SELECTED WINDOWS

FIG3. USING DECISION TREE REGRESSION TO ASSESS THE INFLUENCE OF VARIABLES ON THE LEVEL OF M_EDI.

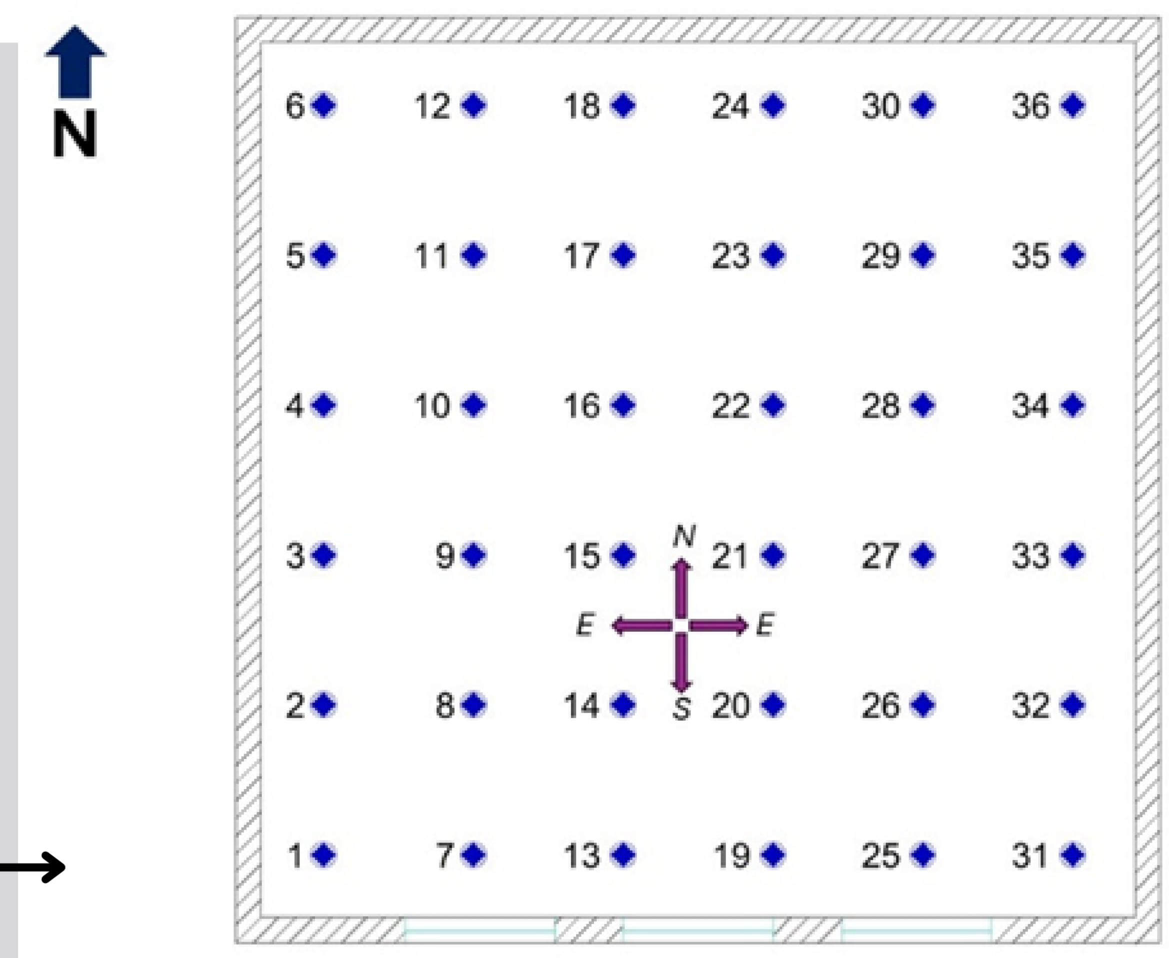
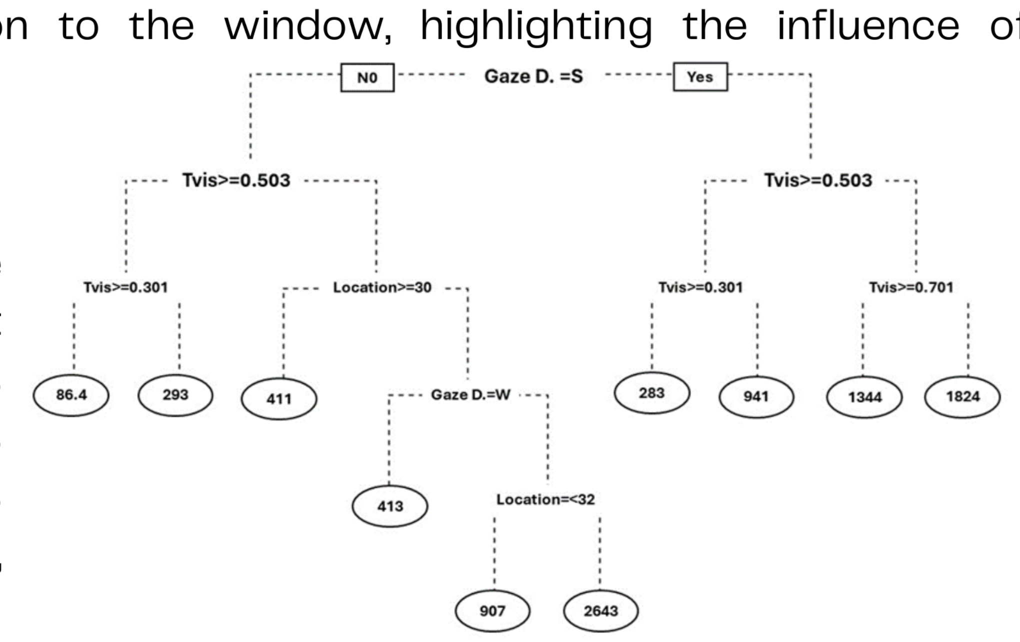


FIG2. PLAN VIEW OF THE SENSORS' LOCATION AND GAZE DIRECTIONS.

RESULTS/FINDINGS

The study used decision tree regression (FIG3) to assess circadian light levels (m_EDI) for various gaze directions and environmental factors. Results indicate that gaze direction is the most influential parameter, followed by window visible transmittance (Tvis). Perpendicular gaze direction consistently exceeds the WELL standard of 250 lux, while deviations and Tvis below 0.301 result in lower exposure. The intercorrelation of variables is evident as a westward gaze direction near walls yields higher circadian illuminance compared to a perpendicular gaze direction to the window, highlighting the influence of environmental factors.



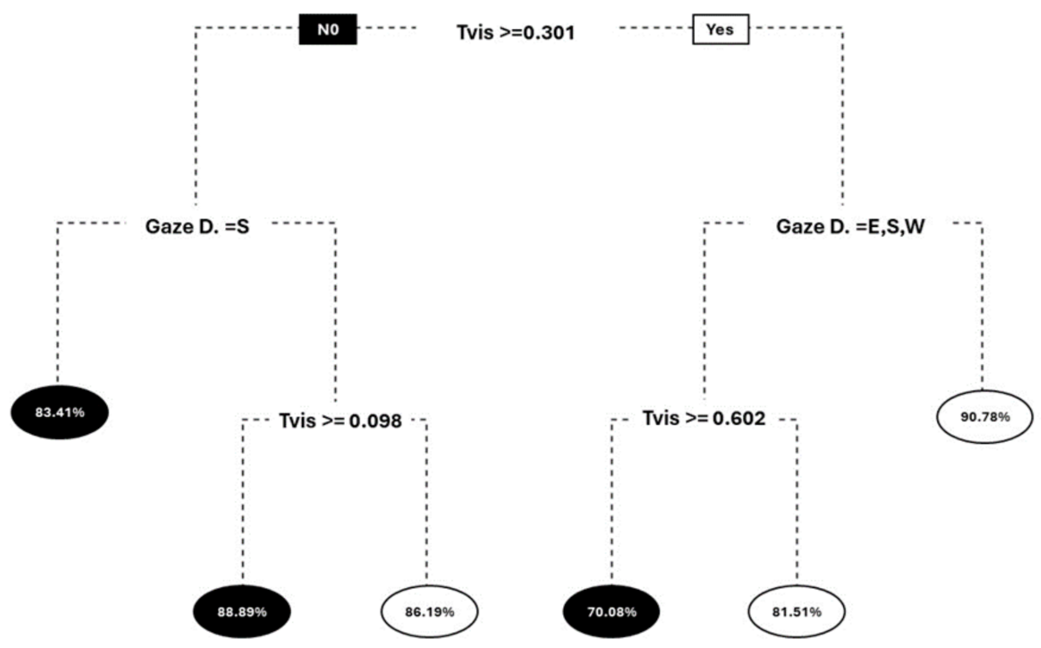
The influence of surface reflectance on circadian light levels (m_EDI) appears limited, particularly in regions adjacent to the window, as shown in Table. However, significant effects of wall reflectance are observed in deeper regions of the room and non-perpendicular gaze directions, with a discernible trend indicating a 9% increase in m_EDI levels for every 10% increase in wall reflectance.

TABLE. SUMMARY STATISTICS OF M_EDI BY SURFACE REFLECTANCE

Surface	Reflectance	Mean	Standard deviation	Variance	Percentage variance (relative to lowest reflectance)
Wall	50%	494.7713	601.8083	362173.2	-
	60%	516.8984	603.9540	364760.5	4.47
	70%	539.6673	607.9916	369653.8	9.07
	80%	562.2699	611.9694	374506.6	13.64
Ceiling	70%	524.2582	602.5969	363123.0	-
	75%	527.1096	605.3231	366416.0	0.54
	80%	529.7859	608.8238	370666.4	1.05
	85%	532.4531	611.0561	373389.5	1.56

In Fig4, decision tree classification shows that for the second half of the room, Tvis is the most important variable to determine m_EDI levels. If Tvis is less than 0.301 and the gaze direction is not perpendicular to the window, the light exposure is below 250 Lux in 83.41% of cases. Conversely, when Tvis exceeds 0.602, and the gaze direction is away from the window, the threshold is met in 81.51% of instances.

FIG4.USING DECISION TREE CLASSIFICATION TO ASSESS THE INFLUENCE OF VARIABLES ON THE LEVEL OF M_EDI ON SECOND HALF OF THE ROOM.



CONCLUSION

In conclusion, our study emphasizes the intricate interplay of various parameters in circadian daylighting dynamics, advocating for a standardized metric to evaluate indoor circadian light distribution. Through simulations utilizing a limited set of glazing samples and varied wall and ceiling reflectance, we underscored the significance of gaze direction and window transmittance as pivotal variables. Despite past doubts regarding the accuracy of Tvis in assessing circadian performance, our research aimed to evaluate its predictive capability alongside other properties. While wall reflectance emerged as noteworthy, particularly in deeper areas of the room, Tvis and gaze direction were found to overshadow its impact. These findings suggest the necessity for ongoing research to comprehensively understand and optimize circadian lighting in indoor environments, especially in larger and deeper spaces.

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REFERENCE

Ghaeili Ardabili , N., Wang, J., & Wang , N. (2023). A systematic literature review: Building window's influence on indoor circadian health. Renewable and Sustainable Energy Reviews. doi:https://doi.org/10.1016/j.rser.2023.113796