PLEA
STGO
2022

November 22 - 25, 2022

WILL CITIES SURVIVE?

The future of sustainable buildings and urbanism in the age of emergency.

BOOK OF PROCEEDINGS VOL 1 ONLINE SESSIONS

PLEA STGO 2022: WILL CITIES SURVIVE?

Conference Chairman
Waldo Bustamante

Co-Chair
Felipe Encinas
Magdalena Vicuña

Editorial Team
Waldo Bustamante
Mariana Andrade
Pablo Ortiz E.

Hosting Organization
Pontificia Universidad Católica de Chile
Avenida Libertador Bernardo O'higgins 340

Graphic Design Project
Nicolás Gutierrez

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PLEA STGO 2022

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ORGANISED BY

Passive and Low Energy Architecture (PLEA)
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PLEA STGO 2022: WILL CITIES SURVIVE?

ABOUT

PLEA Association is an organization engaged in a worldwide discourse on sustainable architecture and urban design through annual international conferences, workshops and publications. It has created a community of several thousand professionals, academics and students from over 40 countries. Participation in PLEA activities is open to all whose work deals with architecture and the built environment, who share our objectives and who attend PLEA events.

PLEA stands for "Passive and Low Energy Architecture", a commitment to the development, documentation and diffusion of the principles of bioclimatic design and the application of natural and innovative techniques for sustainable architecture and urban design.

PLEA serves as an open, international, interdisciplinary forum to promote high quality research, practice and education in environmentally sustainable design.

PLEA is an autonomous, non-profit association of individuals sharing the art, science, planning and design of the built environment.

PLEA pursues its objectives through international conferences and workshops; expert group meetings and consultancies; scientific and technical publications; and architectural competitions and exhibitions.

Since 1982 PLEA has been organizing highly ranked conferences that attract both academia and practicing architects. Past Conferences have taken place in the United States, Europe, South America, Asia, Africa and Australia.

After almost a decade the PLEA conference is coming back to South America, Santiago (Chile), to be organized by the Pontifical Catholic University of Chile (PUC). Inevitably, the theme of PLEA 2022 is inspired by the current pandemic which has put the whole world on alert and makes us rethink our built environment in terms of health and safety. Whereas due to its current social unrest and significant social divide Santiago and South America in general provides a great ground to talk about inequalities and revisit social movements, that spanned around the globe from Lebanon, France to Chile and other countries just before the pandemic hit.

The aim of the PLEA 2022 is to question the whole idea of a city, the way we inhabit and use them generating the definitive inflection point that a sustainable city requires.

GOAL AND THEME

For decades, the climate crisis has been demanding our action and commitment. Numerous efforts to reach an international consensus via climate summits, such as COP25, and Paris Agreement have not had any expected results yet. However, even though the COVID-19 pandemic has intensified the sense of urgency, many talks about climate change were put on hold during 2020, when the new virus put the world on alert.

In no time it has become a global issue and provoked various reactions from political leaders around the world—from absolute denial to the harshest restrictions—adjusting and learning in the process by trial and error.

This process has not been easy as COVID-19 highlighted critical deficiencies in our built environment and urban design. Even though infections battered affluent areas too, the pandemic hit the hardest when the virus reached sectors with high rates of poverty. Dense neighborhoods and overcrowded buildings could facilitate the rapid spread of infections due to the difficulty of generating social distancing and the application of extensive quarantines.

Yet, various changes have been adopted rapidly. Hygiene protocols, wearing masks, social distancing and other strategies has become part of our ordinary life. On top of that, the use of public spaces, streets, parks, homes and all buildings had to be adjusted to control the spread of the virus transforming our habits and conception of them. Numerous studies showed great variations in the use of transportation during the pandemic too. But the questions are: are those changes here to stay? What does the future hold for our built environments?

Some even go as far as to question: Will cities survive? While many intellectuals and academics call for the end of cities (at least as we know them), some stakeholders urge to return to normality, or so-called status quo.

Is this the last opportunity to effectively build a healthy, livable and equitable city? It is clear that cities can no longer be conceived as before and it is time to question the way we inhabit and use them. What are the standards, mechanisms and criteria to define a sustainable city and building? Do they respond to the problems and deficiencies in the age of emergency? History shows us how cities reacted to and changed after health crises similar to COVID-19; this is the time to question everything around us and strive for environmentally sustainable and socially just cities.

The aim of PLEA 2022 is to be a relevant part of the discussion and bring about proposals to the developing and developed world. It is a great chance to talk about the changes that affected cities around the globe since the start of the pandemic and bring the scientific knowledge generated in this short time to the discussion.

Social inequality should also be a part of the debate as both health and climate emergencies may further increase the injustice and, at the same time, the inequality may make such crises worse. Latin America, as the most unequal region, and Chilean case might serve as a great example of such issues and could become a source of inspiration to find the definitive inflection point that a truly sustainable city requires.

WELCOME TO SANTIAGO DE CHILE

Dynamic and cosmopolitan Santiago is a vital and versatile city. Home to many events showcasing the very best of Chilean culture, it also hosts superb international festivals of sound, flavor and color. The Chilean capital breathes new life into all its visitors!

The city's diversity shines through in its many contrasting neighborhoods. Set out to explore the city streets and you'll discover beautiful and original art galleries, design shops and handicraft markets, as well as a great selection of restaurants, bars and cafes. Night owls can enjoy a taste of lively Latino nightlife in hip Bellavista!

Visit downtown Santiago to get a real feel for the city. Learn more about the country in its many fine museums, or wander around the famous Central Market – a gourmet's delight.

Fans of the great outdoors can head for the hills that surround the city and marvel at panoramic views of Santiago with the magnificent Andes as a backdrop. Take the opportunity to grab a picnic and visit one of the city´s many parks.

In Chile there are places that have not seen a drop of rain in decades, while there are others where the rain brings out the green in the millenial forests.

This diversity captivates and surprises its visitors. Because, as a consequence of its geography, Chile has all the climates of the planet and the four seasons are well differentiated. The warmest season is between October and April and the coldest, from May to September.
The temperature in Chile drops down as you travel south. In the north, the heat of the day remains during the day while the nights are quite cold. The central area has more of a Mediterranean climate and the south has lower temperatures and recurring rainfall throughout the year.

The conference will be held at the Centro de Extensión de la Pontificia Universidad Católica de Chile, located at Avenida Libertador Bernardo O'Higgins 390, Santiago, Metropolitan Region. Universidad Católica subway station, Line 1

The Center is located in the center of the city of Santiago, with excellent connectivity to the rest of the city and the most characteristic neighborhoods of the capital, either through the Metro network (Line 1) or other means of public transport such as Transantiago (Santiago's public bus network).

To make your hotel reservations, we recommend looking in the Providencia or Las Condes districts, close to Metro Line 1. We also have some suggestions for accommodation close to the conference venue.

WILL CITIES SURVIVE?: TRACKS

1. Sustainable Urban Development
– Regenerative Design for Healthy and Resilient Cities
– Sustainable Communities, Culture and Society
– Low Carbon Neutral Neighbourhoods, Districts and Cities
– Urban Climate and Outdoor Comfort
– Green Infrastructure
– Urban Design and Adaptation to Climate Change

2. Sustainable Architectural Design
– Resources and Passive Strategies
– Regenerative Design
– Energy Efficient Buildings
– Net-zero Energy and Carbon-neutrality in New and Existing Buildings
– Vernacular and Heritage Retrofit
– Building Design and Adaptation to Climate Change

3. Architecture for Health and Well-being
– Comfort, IAQ & Delight
– Thermal Comfort in Extreme Climates
– IAQ and Health in Times of Covid-19
– Comfort in Public Spaces

4. Sustainable Buildings and Technology
– Renewable Energy Technologies
– Energy Efficient Heating and Cooling Systems
– Low Embodied Carbon Materials
– Circular Economy
– Nature-based Material Solutions
– Water Resource Management and Efficiency

5. Analysis and Methods
– Simulation and Design Tools
– Building Performance Evaluation
– Surveying and Monitoring Methods
– User-building Interaction and Post-occupancy Evaluation

6. Education and Training
– Architectural Training for Sustainability & Research
– Professional Development
– Sustainable Initiatives and Environmental Activism
– Methods and Educational Practices
– Strategies and Tools

7. Challenges for Developing countries
– Energy poverty
– The Informal City
– Climate Change Adaptation
– Affordable Construction and Architecture Strategies
– Urban Planning and Urban Design Policies for Sustainable Development
– Housing and urban Vulnerability

CRISTINA DORADOR

Keynote speaker
CHILE

Between July 2022 and July 2022 she served as a member of Chile's constitutional convention. She is currently back to teaching at the Universidad de Antofagasta.

Chilean scientist, doctor and politician who conducts research in microbiology, microbial ecology, limnology and geomicrobiology. She is also an associate professor in the Department of Biotechnology of the Faculty of Marine Sciences and Natural Resources at the University of Antofagasta. From July 2021 to July 2022 she served as a member of the Constitutional Convention representing District No. 3, which represents the Antofagasta Region.

Her achievements include the coordination in Chile of the Extreme Environments Network for the study of ecosystems in the geographic extremes of Chile and having developed biotechnological tools to value the unique properties of some altiplanic

microbial communities such as resistance to ultraviolet radiation to elaborate cosmetic creams, joining the field of cosmetic Biotechnology. She has also led application projects such as the development of textile material using the photoprotective properties of altiplanic bacteria.

She was a member of the transition council of the National Commission for Scientific and Technological Research in 2019 that gave rise to the National Agency for Research and Development of Chile, and has been recognized nationally and internationally as one of the most relevant researchers in Chile.

ADRIANA ALLEN

Keynote Speaker
ARGENTINA

Professor of Urban Sustainability and Development Planning at The Bartlett Development Planning Unit (DPU), University College London and President of Habitat International Coalition (HIC).

Adriana has over 30 years of international experience in research, graduate teaching, advocacy and consulting in over 25 countries in the global South, she has specialized in the fields of development planning, socio-environmental justice and feminist political ecology.

She is currently President of Habitat International Coalition (HIC), as well as a regular advisor to UN agencies, positions from which she is actively engaged in promoting urban justice through advocacy and policy evidence, social learning and fostering international collaboration both within UCL and globally.Through the lens of risk, water and sanitation, land and housing, food and health, her work examines the interface between everyday city-making practices and planned interventions and their capacity to generate transformative social and environmental relations.

Adopting a feminist political ecology perspective, her work combines qualitative, digital/mapping, and visual research methods to decolonize urban planning practices and elucidate the "cracks" in which transformative planning can be reinvented, nurtured, and pursued. Her work focuses on three interrelated themes: urban justice, everyday city-making, and transformative planning.

Over the years, she has worked at the interface between insurgent practices and planned interventions and their capacity to generate socio-environmentally just cities.

This work stems from her engagement with the analysis of governance approaches to address structural deficits at the interface between "policy-driven" and "needs-driven" approaches and emerging improvements at scale – in water and sanitation, as well as in other areas such as food security, land, housing and health. Since 2008, she has explored the intersection of urbanization and climate change, with a particular focus on the generation and distribution of risks, vulnerabilities and capacities for action in southern cities. A third strand of her research focuses on urban planning as a field of networked governance and pedagogical strategies to decolonize planning education and shape pathways for urban equality.

ANACLAUDIA ROSSBACH

Keynote speaker
BRAZIL

Economist with a track record of more than 20 years working on the issues of slums, social housing and urban policy.

She is currently Director for Latin America and the Caribbean at the Lincoln Land Institute of Policy. She also serves as a member of the editorial board of Vivienda magazine of INFONAVIT – México. And previously she worked as a consultant on housing and urban development issues for the IDB (Inter-American Development Bank).

She worked in the Prefecture of São Paulo, supporting the Brazilian Ministry of Cities in the design and implementation of the Brazilian housing policy. She founded and served on the board of directors of the NGO INTERAÇÃO, which supported the development of high-impact projects in communities in the state of São Paulo and Recife.

As a senior consultant to the World Bank, she provided technical assistance for the development and implementation of Brazilian housing policy and slum upgrading for 10 years, including two major programs: the "PAC Favelas" slum upgrading and the "Minha Casa, Minha Vida" housing subsidy.

She acted as a senior specialist in social housing for the World Bank and other research and project organizations in Brazil and several countries around the world such as the Philippines, China, India, South Africa and Mozambique, among others.

She was Regional Manager for Latin America and the Caribbean for the Cities of Alliance Global Informality Program where the exchange of experiences and knowledge through different networks was consolidated and structured.

The main achievements in Latin America are the Urban Housing Practitioners Hub (UHPH), which brings together practitioners and networks working in the field of social housing. In the global south, multi-sectoral and disciplinary communities of practice on the theme of slum upgrading in the global south with emphasis on the countries: Mexico, Guatemala, El Salvador, Paraguay, Brazil, South Africa and India.

GIANCARLO MAZZANTI

Keynote Speaker
ARGENTINA

Born in Barranquilla, a port city in northern Colombia, Giancarlo Mazzanti is an architect graduated from Pontificia Universidad Javeriana with postgraduate studies in industrial design and architecture in Florence, Italy.

He has been a visiting professor at several Colombian universities, as well as at world-renowned academic institutions such as Harvard, Columbia and Princeton, and is the first Colombian architect to have his works in the permanent collection of the Museum of Modern Art in New York (MoMA) and the Centre Pompidou in Paris.

Giancarlo has more than 30 years of professional experience and his studio, El Equipo Mazzanti has gained notoriety due to its design philosophy based on modules and systems, which generate flexible elements capable of growing and adapting over time, seeking an architecture that is closer to the idea of strategy than to a finite and closed composition. The idea of architecture as an operation was born from exploring the different forms of material and spatial organization, considering concepts such as repetition, the indeterminate, the unfinished, instability, arrangement and patterns.

Equipo Mazzanti also stands out for its research on play and its link to the world of architecture. It is precisely this interest in the play-architecture relationship that has led it to seek new collaborations with professionals from different areas of knowledge, finding new opportunities for cooperation and developing projects and exhibitions that have been presented throughout the world under the We play You play brand.

Social values are at the core of Mazzanti's architecture, who seeks to realize projects that give value to social transformations and build communities. He has dedicated his professional life to improving the quality of life through environmental design and to the idea of social equality.

His work has become a reflection of the current social changes occurring in Latin America and Colombia, demonstrating that good architecture manages to build new identities for cities, towns and inhabitants, transcending reputations of crime and poverty.

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Architect from the University of Concepcion. Master of Architecture from the University of Washington, USA. PhD in Architecture from the University of Oregon. Researcher of the Centre for Sustainable Urban Development (CEDEUS) and Assistant Professor of the Department of Architecture, University of Concepcion.

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École Polytechnique Fédérale de Lausanne. SWITZERLAND.

Feng Yang
Tongji University. CHINA.

Simos Yannas
Architectural Association. UNITED KINGDOM.

Aram Yeretzian
American University of Beirut. LEBANON.

Gabriela Zapata-Lancaster
Cardiff University. UNITED KINGDOM.

Daniel Zepeda
University of A Coruña. SPAIN.

Antonio Zumelzu
Universidad Austral de Chile. CHILE.

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At: **36th PLEA CONFERENCE**
WILL CITIES SURVIVE? The future of sustainable buildings and urbanism in the age of emergency

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PLEA SANTIAGO 2022
Will Cities Survive?

Lighting and daylight control strategies using LabVIEW for optimizing visual comfort and energy savings

ARIS BUDHIYANTO[1,2] YUN-SHANG CHIOU[1]

[1] National Taiwan University of Science and Technology
[2] Petra Christian University

ABSTRACT: This study presents control strategies based on the National Instrument Laboratory Virtual Instrument Engineering Workbench (NI LabVIEW) platform to reduce energy consumption as well as maintain visual comfort by controlling lighting fixtures and window blinds. A model prototype is presented equipped with motorized blinds and dimming lights controlled by NI LabVIEW, and light sensors for monitoring the indoor illuminance value. The results show that the model prototype performs well in maintaining uniformity of illuminance value. An annual simulation using Rhino/Grasshopper predicted that visual comfort can be well maintained by window blinds that rotate 45^0 (half-closed) without turning on one lamp, mostly during the daytime when the sky condition is clear; therefore, lighting energy consumption can be reduced by around 16%.

KEYWORDS: LabVIEW, energy efficiency, visual comfort, building automation, integrated control

1. INTRODUCTION

According to data on U.S. building sector energy consumption, buildings consumed about 39% of the total energy in the U.S., of which about 35% is accounted for by lighting (Brasington, 2019). Daylight utilization in buildings shows great potential for energy savings. To evaluate the performance of daylight utilization technologies, illuminance levels and uniformity need to be considered (Chiou & Lin, 2016). Optimum visual performance requires a certain level of uniformity across the working plane (Freewan & Al Dalala, 2020). Therefore, useful daylight illuminance (UDI) is mostly used for the simple evaluation of lighting design in architecture and visual discomfort (Galatioto & Beccali, 2016; Tabadkani et al., 2019). Based on occupants' behavior, visual comfort has mostly focused on working plane conditions (Galatioto & Beccali, 2016; Husin & Harith, 2012). Working plane illuminance levels between 500 and 2000 lux are sufficient for the visual task and for achieving visual comfort (Chaloeytoy et al., 2020).

Hirning et al. (2017) indicate that some sustainable buildings across 10 countries have some issues of visual discomfort from glare, causing building occupants to usually close window blinds. To cope with that problem, several control strategies are applied. Control strategies for controlling window blinds and lighting are essential to improve visual performance (Chan & Tzempelikos, 2013) and achieve energy savings from 30 to 50% (Konstantoglou & Tsangrassoulis, 2016). There are two control strategies for lights and blinds: independent and integrated. In an independent control strategy, the control systems control the lights and blinds separately using different sets of points and controllers, whereas in an integrated control strategy both lights and blinds are controlled using the same set point. Rule-based algorithms and co-simulation with EnergyPlus, BCVTB, and MATLAB are the common methods used in those control strategies (Mukherjee et al., 2010; Plörer et al., 2021). However, the programming languages used in those methods, such as C++, Python, or MATLAB, involves advanced programming skills to run them.

Instead of using those programming languages, this study presents control strategies based on the LabVIEW (Laboratory Virtual Instrument Engineering Workbench) environment, a graphical programming environment widely used for measuring, monitoring, controlling, and recording operating conditions (Chinomi et al., 2017). LabVIEW is preferred because it supports thousands of hardware devices and recent technologies but keeps using common protocols and requires no programming skills (Hamed, 2012).

This study aims to maintain visual comfort by implementing an integrated control strategy to control the lighting fixtures and window blinds using LabVIEW, and to investigate the energy consumption reduction for lighting. A whole-year simulation is conducted to analyze the performance of the control system and annual energy saving.

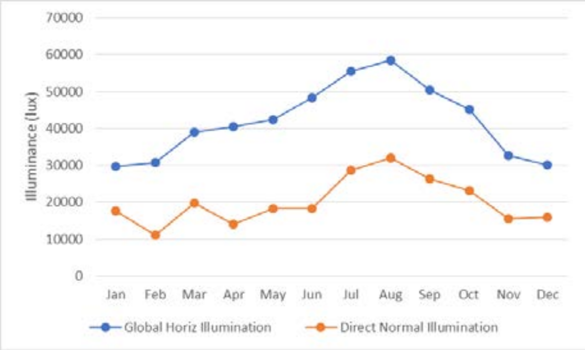
2. METHOD

This study applies an experiment method and a simulation method. An experiment using a model prototype was conducted to test and validate the algorithm building in LabVIEW while a simulation using building performance simulation software was used for simulating the indoor lighting performance and energy saving.

2.1 Daylight in Taiwan

Taipei, Taiwan, is selected as the location for this study. Located on 25°04′N 121°31′E, the hours of daylight/day in Taipei are between 10:35 hours (winter) and 13:39 hours (summer) while the annual hours of daylight are 12 hours (*Sunshine & Daylight Hours in Taipei, Taiwan*, n.d.). The average hourly global horizontal illumination is between 29,607 lux (winter) and 58,435 lux (summer); meanwhile, the average hourly direct normal illumination is between 11,128 lux (winter) and 32,066 lux (summer) (Fig. 1).

Figure 1:
Monthly daylight illumination in Taipei



Note: This figure is modified from the Taipei-Songshan weather data file.

To understand the daylight condition in a building, a simulation was conducted using Rhino/Grasshopper simulation software. Ladybug and Honeybee plugins were used to simulate the daylight and energy performance. A comparative study between Rhino/Grasshopper, DIVA, and Design Builder for analyzing illuminance level and energy consumption was conducted to validate the simulation model. The results showed that the indoor illuminance difference between Rhino/Grasshopper and Diva simulation is in the range of 10–20%, while the energy simulation difference between Rhino/Grasshopper and Design Builder is less than 10%.

A model with 8.2 m length x 3.6 m width x 2.8 m height (length:width was approximately 2 and length:height was approximately 3) and with a south-faced window was built in Rhino/Grasshopper simulation software (Fig. 2) to identify the daylight condition inside the building. The material reflectance of the ceiling, wall, floor, and surrounding ground was 0.8, 0.5, 0.2, and 0.8, respectively. Spatial daylight autonomy (SDA) and useful daylight illuminance (UDI) were simulated. The simulation results showed that there was a huge range of the illuminance level in the building, where the southern area near the window received abundant daylight and had a high illuminance level while the northern area did not receive any daylight. Figure 3 shows that the room was divided into three zones: high daylight zone (A), intermediate daylight zone (B), and low daylight zone (C). To solve that problem, a shading device was required to reduce the daylight for zone A while artificial lighting was required to provide enough lighting for zones B and C.

Figure 2:
Model built in Rhino/Grasshopper simulation software.

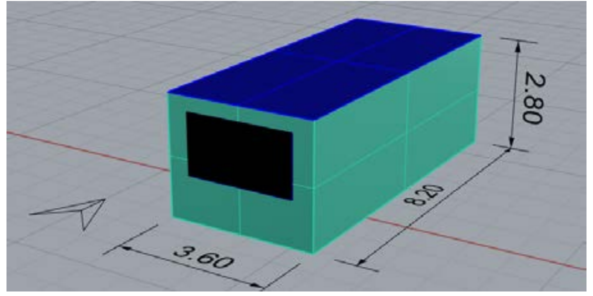
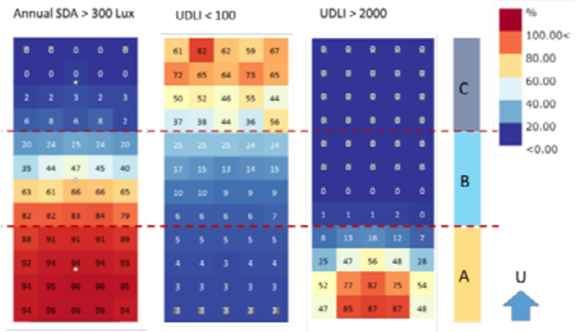


Figure 3:
Annual SDA and UDI simulation results.



Annual SDA > 300 Lux

0	0	0	0	0
0	0	0	0	0
2	2	3	2	3
6	8	6	8	2
20	24	25	24	20
35	44	47	45	40
63	61	66	66	65
82	82	83	84	79
88	91	91	91	89
92	94	94	94	93
94	95	96	96	95
94	96	96	96	94

UDLI < 100

61	82	62	59	67
72	65	64	73	65
50	52	46	55	44
37	38	44	36	56
25	25	25	24	24
17	15	13	14	15
10	10	9	9	9
6	6	6	6	7
5	5	5	5	5
4	4	3	4	4
3	3	3	3	3
3	3	3	3	3

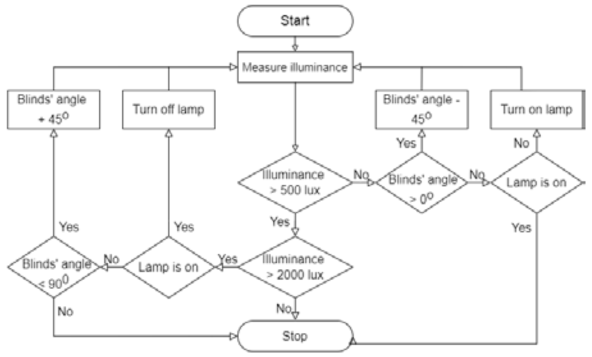
UDLI > 2000

0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
1	1	1	2	0
8	13	16	12	7
25	47	56	48	28
52	77	82	75	54
47	85	87	87	48

2.2 Control strategies algorithm

The light and blind control strategies are used to maintain indoor illuminance in the range of 500–2000 lux. Figure 4 shows the algorithm flow of the control strategies. As the initial condition, the lamp is turned off and the blind angle is set to 0^0 (blind opened). When the indoor illuminance is lower than 500 lux, if the blind angle is higher than 0^0, then it will reduce by 45^0 until it becomes 0^0 (blinds opened) and the lamp will turn on. When the indoor illuminance increase is higher than 2000 lux, the lamps will be examined first; if the lamp turns on, it will turn off. Later, the blind angle will gradually rotate 45^0 until the angle becomes 90^0 (blinds closed). The lamp and blinds remain steady in their current condition when indoor illuminance is between 500 and 2000 lux. This process is repeated every minute.

Figure 4:
Algorithm flow of the control strategies.



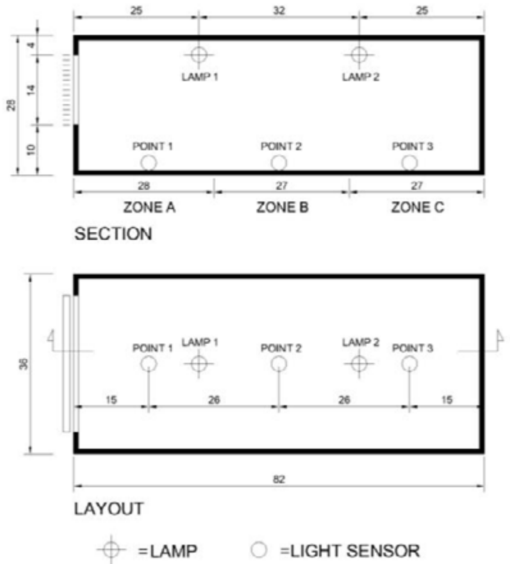
3. EXPERIMENTAL STUDY

3.1 Model prototype

A model with 82 cm length x 36 cm width x 28 cm height was built to analyze the illuminance level. The model had a window and was equipped with motorized blinds and light controlled by NI (National Instrument) LabVIEW. Several LED Fresnel lamps were placed outside the box and their lights were directed to the window to provide daylight. During the measurement, the LED Fresnel was brightened and dimmed gradually to change the light intensity penetrating the box (Fig. 5). Three illuminance sensors were presented inside the box in each zone for monitoring the indoor illuminance and an illuminance sensor was placed outside the box to monitor outdoor illuminance values. As using three lamps resulted in indoor illuminance exceeding 2000 lux, two lamps were used in the prototype, but only lamp 1 put between zone A and B was controlled by the control system because lamp 2 (put between zones B and C) needed to be turned on all the time to provide illuminance of more than 500 lux for zones B and C (Fig. 6).

Figure 5:
Model prototype equipped with motorized blind and lighting fixtures.

Figure 6:
Layout plan and section of the model



Note: The dimension is in cm.

3.2 Model prototype testing

The control strategies applied to the prototype indicate that it can maintain indoor illuminance values in a range of 500–2000 lux regardless of large changes to outdoor illuminance. Figure 8 shows the results of indoor and outdoor illuminance monitoring and Fig. 9 shows the blind angle and lamp condition for 120 minutes. Blind angle 90^0 indicates that the blinds are closed while 0^0 indicates the blinds are opened; 0 indicates that the lamp turns off and 1 indicates that it turns on.

During the experiment, the illuminance values of points 1 and 2 change because they are greatly affected by the outdoor condition (the LED Fresnel lamps), and lamp 1 controlled by NI LabVIEW; however, the illuminance values of point 3 do not change significantly because lamp 2 always turns on. In the beginning, the outdoor illuminance value is very low, which causes lamp 1 to turn on. As the outdoor illuminance value increases, at minute 20, the indoor illuminance value point 1 exceeds 2000 lux, resulting in lamp 1 being turned off at the next minute and the indoor illuminance values decreasing below 2000 lux. At minute 42, the illuminance values of point 2 exceed 2000 lux. Because lamp 1 is already turned off, the blinds rotate 45^0 at the next minute to reduce the indoor illuminance values.

Starting from minute 70, the LED Fresnel lamps were dimmed gradually to reduce the outdoor illuminance. From minute 43 to minute 95, the condition of the blinds and lamp do not change. But at minute 95, indoor illuminance values at points 1 and 2 are under 500 lux, causing the blinds' angle to change to 0^0 and illuminance points 1 and 2 to increase higher than 500 lux. As outdoor illuminance is reduced continuously, at minute 108, lamp 1 turns on because illuminance values of points 1 and 2 are lower than 500 lux. The condition of the blinds and lamp do not change until the end of the measurement (minute 120).

Figure 8:
Indoor and outdoor illuminance monitoring.

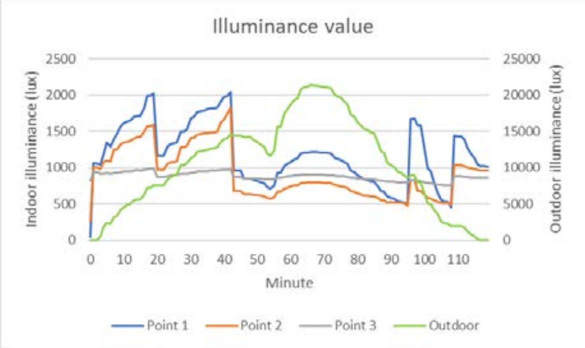
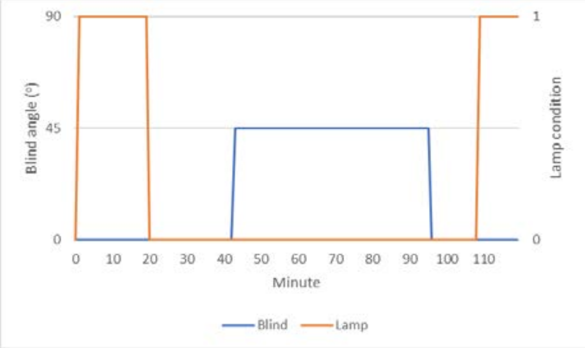


Figure 9:
Blind angle and lamp condition monitoring.



4. SIMULATION STUDY

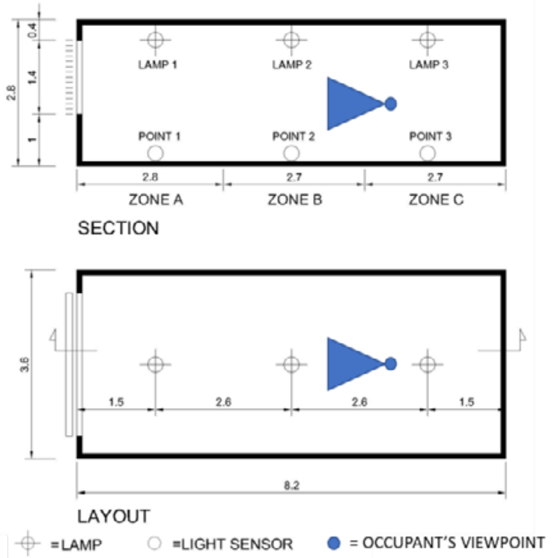
4.1 Simulation setting

The control system was implemented in the form of simulation in Rhino/Grasshopper software with Ladybug and Honeybee plugins to analyze the annual energy saving. A model with 8.2 m length x 3.6 m width x 2.8 m height was built in Rhino/Grasshopper simulation software. A window blind was installed on the south-facing window and three lamps were installed inside the model to provide uniform illuminance values when there is no daylight in the room; however, only lamp 1 in zone A was controlled because lamps 2 and 3 in zones B and C were needed to be turned on all the time to achieve the working plane illuminance levels between 500 and 2000 lux (Fig. 10).

In addition to indoor illuminance, glare analysis was conducted to evaluate visual comfort. DGP (daylight glare probability) and DGI (daylight glare index) are the common indices to analyze glare discomfort (Galatioto & Beccali, 2016). The glare analysis point of view was set 6 m from the window and at a height of 1.2 m (Fig. 10).

A typical day in spring, summer, and winter (March 21st, June 22nd, and December 21st) was simulated to represent the lighting condition for the shoulder (spring and fall), summer, and winter seasons in a year, respectively. The simulation was carried out using the weather data file of Taipei-Songshan under the clear sky condition. Based on the simulation, the window blind angle and lamp schedule for a year were obtained. Later, an annual energy simulation was conducted using the blind angle and lamp schedule.

Figure 10:
Layout plan and section of the model built in Rhino/Grasshopper simulation software.



Note: The dimension is in m.

4.2.1 Indoor visual comfort

The control system built in the LabVIEW platform was applied to the Rhino/Grasshopper simulation to control the window blind angle and lamp condition. Figure 11 shows the illuminance values of the simulation results. Because lamps 2 and 3 placed on zones B and C always turn on, the illuminance values of points 2 and 3 are in a range of 500–2000 lux; however, the illuminance value of point 1 changes based on the daylight and blinds and lamp 1 condition. In the shoulder season, the illuminance value of point 1 exceeds 2000 lux at 9:30, causing the blinds to rotate 45^0 (half-closed) at 9:31 to reduce the illuminance value. The blinds maintain that position until 16:20 and rotate to the initial condition at 16:21 because at 16:20 the illuminance value of point 1 is 488 lux, which is lower than the requirement. After return to the initial condition, the indoor illuminance value of point 1 raises to 870 lux at 16:21 but gradually decreases. At 16:57, it decreases to 463 lux, causing lamp 1 to turn on after 16:57. Figure 12 shows the blind angle and lamp 1 condition.

In the summer season, the indoor illuminance values of three measurement points are within the range of 500–2000 lux during the daytime, but after

16:30 the illuminance value of point 1 is lower than 500 lux, causing lamp 1 to turn on. Different from the other seasons, in winter the blinds rotate to 45^0 from 9:00 until 16:10 and rotate to 0^0 at 16:11 — longer than in other seasons— and the lamp turns on earlier, at 16:20. This condition can be explained in the summer season as the south-faced window façade receives less daylight compared to other facades but in the winter season receives more daylight than other façades; however, the time duration is shorter than other seasons.

Figure 11:
Indoor illuminance values during the shoulder, summer, and winter seasons.

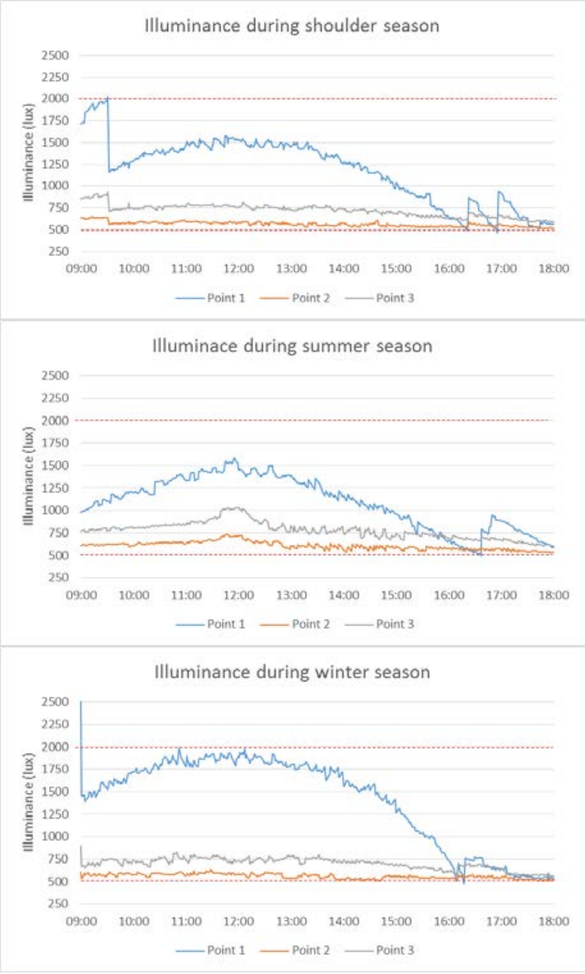
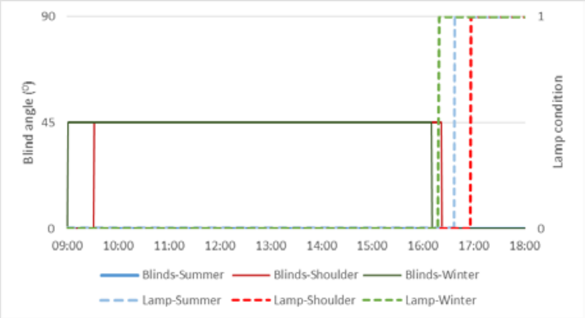


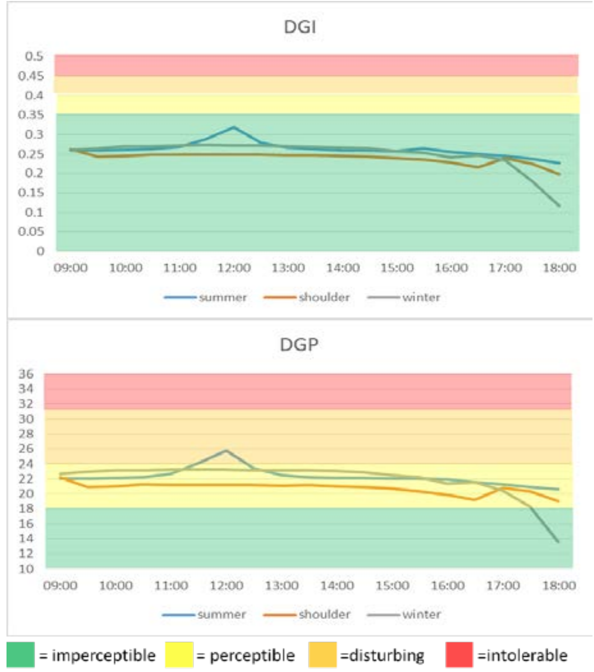
Figure 12:
Annual blind angles and lamp 1 condition.



The simulation results indicate that for almost the whole year, when the sky is clear, the blinds need to be half-closed (rotated to 45^0) in order to avoid excessive illuminance and visual discomfort. Because the illuminance value of point 1 is within the required range, lamp 1 does not need to be turned on mostly during the daytime.

Figure 13 shows the results of glare analysis for a typical day in the shoulder, summer, and winter seasons. Based on the values of DGP and DGI, the glare perceived is still able to be tolerated. All DGI values below 0.35, which indicates that the glare index is imperceptible while most DGP values are between 18 and 24, which indicates that the glare probability is perceptible and in the summer at noon the glare is disturbing.

Figure 13:
Glare analysis during the shoulder, summer, and winter seasons.



4.2.2 Energy savings

A simulation is conducted using the blinds and lamp schedule in Fig. 12 for analyzing energy consumption. The results are compared to the base case in which the simulation is conducted using a model without window blinds and all three lamps turn on from 9:00 to 18:00 for the whole year. An annual energy saving is presented in Table 1. Implementing the lighting control can reduce energy saving for lighting only by around 30% as the room depth is greater than the width, and only one lamp can be turned off during the daytime. By considering the energy consumption of the additional equipment for controlling the lights and blinds, the energy savings is about 16.19%.

Table 1: Annual energy savings prediction.

	Base Case	Model
Lighting (kWh/yr.m^2)	19.05	12.88
Equipment (kWh/yr.m^2)	-	3.09
Total (kWh/yr.m^2)	19.05	15.97
Savings (kWh/yr.m^2)	-	3.08
Savings (%)	-	16.19

5. CONCLUSION

This study presents lighting and daylight control strategies using LabVIEW to improve indoor visual comfort. The control strategies successfully maintain indoor illuminance between 500 and 2000 lux in various outdoor illuminance conditions. The simulation using the weather file of Taipei shows that shading devices are needed to control the indoor illuminance values and maintain visual comfort. In this case, venetian blinds rotated 45^0 need to be installed on the south-facing window. Only during the summer season, the venetian blinds do not need to be rotated 45^0. The simulation results show that applying the control strategies successfully maintains indoor illuminance within the comfort range and reduces glare discomfort.

The annual energy savings prediction indicates that control strategies implementation can potentially reduce energy consumption by 16.19%. Although the number is not great, implementing the control system is mostly able to achieve indoor visual comfort.

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