HOLISTIC LIGHTING DESIGN THROUGH ADAPTIVE STRATEGY FOR SUSTAINABLE LIT ENVIRONMENT: NINGBO ACADEMICIAN CENTER EXTERIOR LIGHTING AS A PILOT CASE STUDY

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ABSTRACT

Artificial light at night (ALAN) in outdoor environment not only supports our visual function after dark, shapes our night time experience under current circumstance, but also has influence on our health and well-being, causes ecological consequence in the long term. Currently, exterior lighting practice is mostly guided by visual effect, but leave non-visual effect and eco-impact behind. To embrace the complexity of these nocturnal challenges, exterior lighting design need to take a holistic approach to achieve a both human-scaled and eco-friendly lit environment at night. By leveraging the advantage of adaptive lighting system and evidence-based methodology, a sustainable lighting design framework is studied and developed in this paper. With the pilot case study of Ningbo Academician Center exterior lighting, the design process under this framework is demonstrated. The lighting solution presents a holistic lighting strategy with adaptability to improve the sustainability of urban night-time space.

Keywords: ALAN, holistic lighting design, adaptive lighting, evidence-based practice, sustainability

1. INTRODUCTION

Today, artificial light at night (ALAN) plays a critical role in the built environment after dark. During the night time, outdoor illumination can not only enable our visual function for all kinds of activities, but also evoke our emotion through the perception of the lit environment [1]. For the former, exterior lighting design usually adopts a quantitative approach to provide appropriate and adequate light, according to strict technical lighting standards, for the visual tasks based on the nature of the space. For the latter, a qualitative methodology is often applied by exterior lighting designer, to explore the complex issues involving people's behaviour, psychology and experience. However, qualitative and quantitative methods are not mutually exclusive. Both of them are simultaneously used in exterior lighting practice to achieve a promising and balanced result [2].

Along with more and more ALAN being used in the build environment, its impact on public health and wellness attracts increasing attention. Inappropriate outdoor lighting application may damage observer's vision, interfere human biological rhythm, affect visitor's mood and cognition, even raise certain disease risks in the long term [3]. At the same time, artificial night lighting also causes comprehensive ecological consequence in nature environment including flora and fauna [4]. The adverse effects caused by ALAN is recognized as light pollution,

which increases rapidly over the past years and is becoming a global issue as sustainability is a global consensus on urban development for a better future [5]. During the past decades, the research on ALAN has provides more and more evidence about night-time illumination as a pollutant that disrupts biological rhythm both in human and nature. Since these issues are much related with health, wellbeing and organism, evidence-based design (EBD), which is adapted from evidence-based medicine, is applied in lighting practice as a methodology [6].

Due to the complexity of these nocturnal challenges, it is hard to take these methods fragmentedly to achieve a sustainable lit environment at night. A more integrated approach, which is not only human-scaled but also eco-friendly, can be developed and applied under a more holistic framework (Figure 1), to shape a better night-time experience by exterior lighting design.

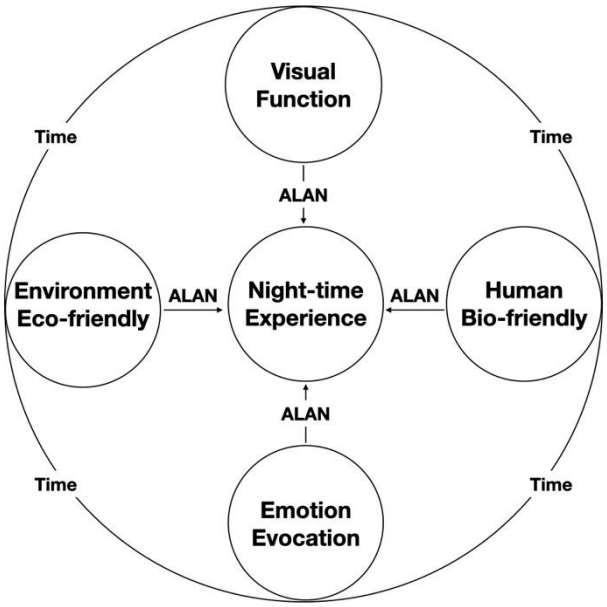

Figure 1. Holistic Exterior Lighting Design Framework

With this framework, Ningbo Academician Center exterior lighting project is taken as a pilot to explore a more holistic and sustainable lighting design practice. Located in a traditional village at the foot of Tao Gong Mountain and by the side of Dong Qian Lake, Ningbo Academician Center is rebuilt on the site of the former Ningbo Normal University, which was established in 1962. As an advanced campus for national academicians, it is composed of Academic Complex Building (formerly East Building), Design and R&D Building (formerly West Building), Visitor Center (formerly Canteen), Tao Gong Auditorium (formerly Dormitory), the elevated bridge and the observation tower (formerly water tower). As a rural renewal program with rich context of history, culture and nature (Figure 2), this case study demonstrates a holistic lighting design methodology with an integrated solution supported by adaptive lighting system.

Figure 2. Ningbo Academician Center: A Rural Renewal Program with Rich Context of History, Culture and Nature

2. METHODOLOGY

Every lighting project is unique in terms of envisioning, context, experience and technology. For Ningbo Academician Center, by interviewing and nightwalking with its professional design team and stakeholders, the consensus is that the exterior lighting design needs not only to functionally and aesthetically support the night-time use of the facilities for all kind of working and visiting group especially including senior scholars, but also reduce the impact on its fragile nature and social environment, which is also critical to the success of this rural renewal program.

By closely working with the development agency, masterplan architect and landscape architect, the vision of Ningbo Academician Center lit environment has been developed before commencing exterior lighting design, which is to create a functional, vibrant, healthy and sustainable night-time place with local connection. It's clear that lighting impacts on both human and environment need to be carefully put into an overall consideration. In order to achieve this vision, a holistic approach integrated quantitative and qualitative methods with evidence-based method is proposed to apply throughout the design process (Figure 3).

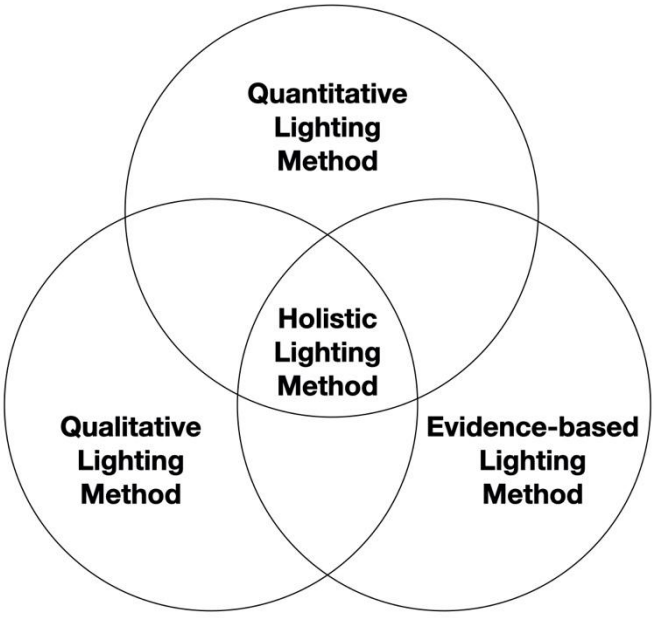

Figure 3. Holistic Lighting Design Method

2.1 Concept

With the understanding of the context and the vision of Ningbo Academician Center outdoor lighting, a general concept of 'harmony of light and darkness' is developed and presented. A lighting hierarchy is planned in line with the principals of the urban design and architectural masterplan, which fully respect the functional positioning of the building elements and address the ecological challenge of the nighttime environment within the scope of the project base and its adjacent area (Figure 4).

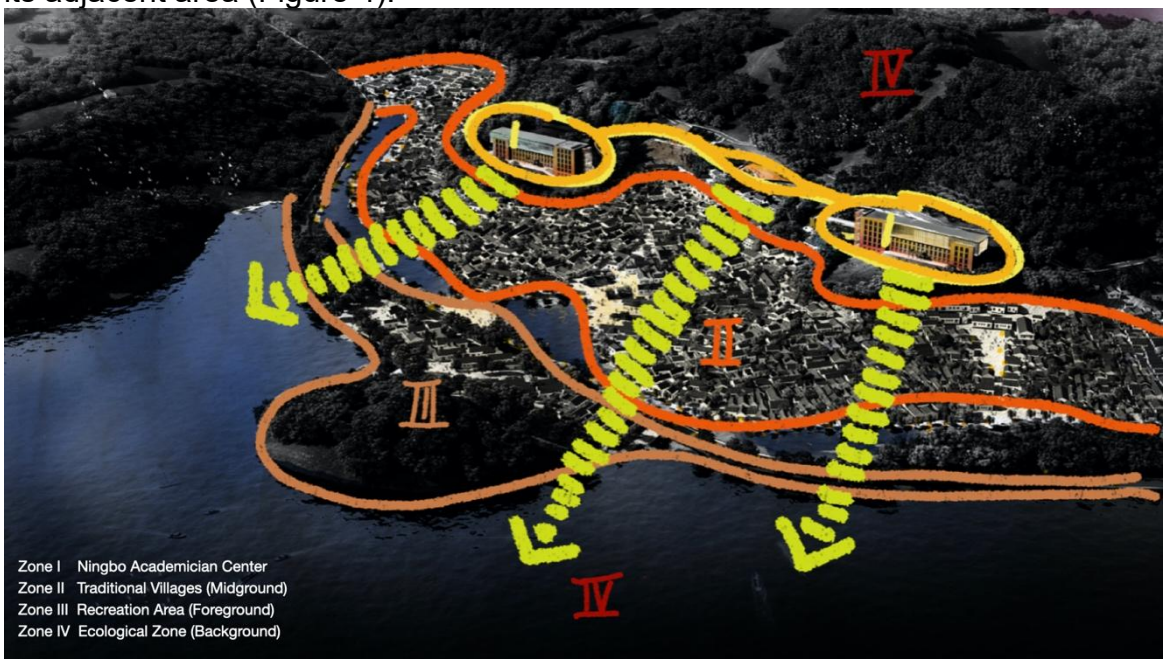

Figure 4. Lighting Hierarchy Overview

This concept running throughout the project means a clear direction to explore the exterior lighting design. Firstly, the balance between the illuminated project and its dark background needs to be carefully maintained, especially to avoid over lighting for these crucial architectural elements. Secondly, the balance between the vision function and the biological impact needs to be fully considered, since the major group using these facilities includes young or senior intellectuals with long working time. Lastly, the balance between the safety of the place and the disruption of the ecological environment needs to be coordinated, to minimise the negative effects of light pollution under the premise of ensuring safety and providing reassurance.

2.2 Schematic design

Under the proposed concept, a schematic design is generated through the holistic lighting design method, which involves quantitative, qualitative and evidence-based approaches to evaluate its rationality and feasibility.

Identity and equivalence play significance roles in the perception of places [7]. Outdoor lighting to reveal the characters of these main buildings' facades is critical for creating a night-time legibility and imageability of the development [8]. However, over focus on presenting the building's details themselves might lose the overall design intention, especially with a dark background of the site. The 'balance' strategy taken from the concept exactly addresses this challenge. By

leveraging the mellow light from the large interior of the main buildings, and combining with the delicate floodlight on those distinctive architectural features such as the red brick walls, a strong sense of place can be created with visual comfort and pleasure. Only the necessary amount of light is used on the façade to illuminate the buildings (Figure 5).

Figure 5. Lighting Scheme for the Main Buildings

The elevated bridge meandering in the development is the major pedestrian route to connect the four main buildings. It serves as an iconic public space, not only for commuting, but also for lingering and social interaction. For outdoor public space engaging all kind of users and activities after dark, lighting has great influence on shaping night-time experience, which can be evaluated by sociability, comfort and image, access and linkage [9]. The lighting scheme for the elevated bridge adopts an integrated solution to address all these challenges. The handrail lighting contributes sufficient horizontal illuminance at floor level. The indirect diffuse light from the vault provides high-quality vertical illuminance at face level. An adaptive scheme with tunable colour temperature and dimming is also introduced in the design, to response these variables of the surrounding over time, such as daylight, occupancy, pedestrian flow, biological and ecological rhythm (Figure 6). Overall, the elevated bridge becomes an attractive and comfort place at night, where light not only enhances safety and reassurance, but also promotes communication and social interaction. At the same time, the spill light is carefully controlled in a minimum level to reduce the negative impact on its precious nature environment.

Figure 6. Lighting Scheme for the Elevated Bridge with Adaptive Scenarios

The lighting scheme for the pathways and other landscape elements follow the same principle of balance taken from the concept. Lighting columns are only used for the main route on the perimeter area to avoid unexpected intrusion. Lighting from lower position is adopted to achieve a more pleasant experience with great visual comfort, as long as the compliance of lighting code is met (Figure 7). An adaptive strategy with real-time dimming is also applied to satisfy the different uses at different time, to save energy and minimise ecological impact at night. The colour temperature of the ambient lighting is limited under 3000K to further reduce the negative effect on biological rhythm.

Figure 7. Low Position Lighting for the Pathway

2.3 Design development

To further develop the lighting scheme established through the proposed holistic design method, besides the compliance of lighting codes, the adaptability of lighting and its control strategy need to be fully leveraged and evaluated, to support the vision of this project, which is to shape a functional, vibrant, healthy and sustainable night-time place with local connection. Coherently, such design

development needs to be deployed under the same holistic framework, which involves lighting analysis, lighting parameter determination and adaptive lighting setting. The elevated bridge lighting design development demonstrates an example of this process.

Based on the schematic design, the handrail lighting and the vault lighting work together to create a safe and comfort place at night. A lighting simulation, mock-up, calculation and testing is fundamental to make sure all lighting code should be met by the regulation from quantitative perspective, and the luminance contrast ratio needs to be maintained in an appropriate range (less than 10:1 in this case) from qualitative perspective (Figure 8).

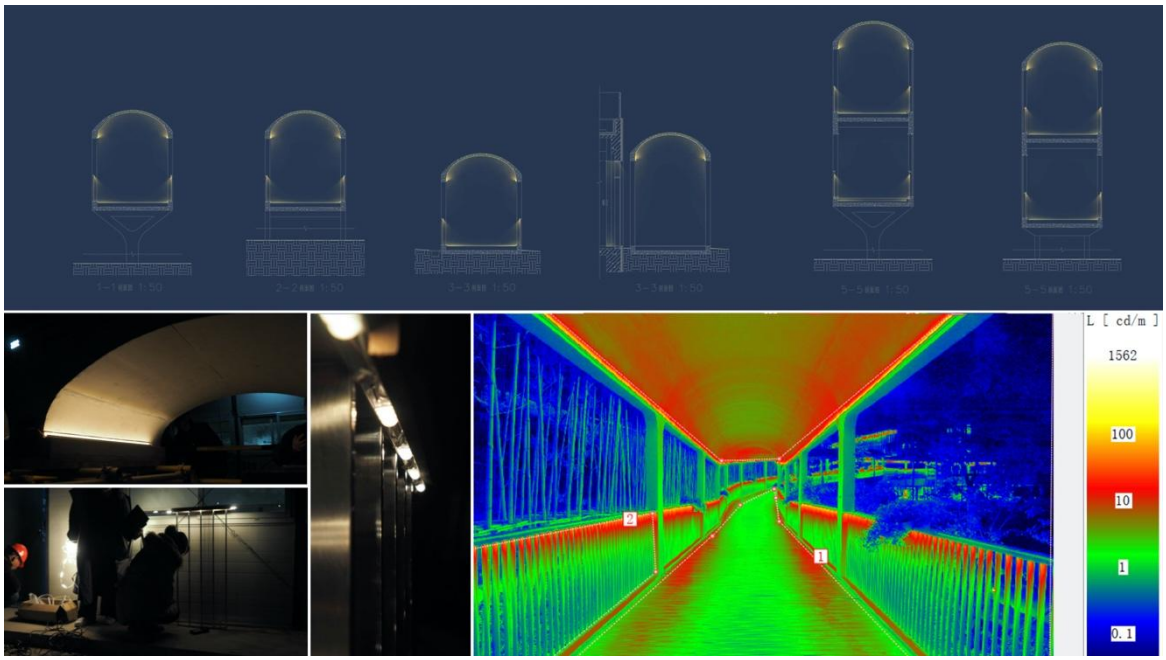

Figure 8. Lighting Simulation, Mock-up, Calculation and Testing

The realization of these adaptive lighting schemes mostly relies on the adaptive lighting setting deployed by design development. An intelligent lighting control system integrated with smart sensors to is used in the elevated bridge, to detect user actions and environmental factors. The data gathered from the sensors is applied as input to generate the corresponding lighting scenarios, to dim the light level when less activity is present, or to tune the colour temperature down to 2200K when ecological impact is more concerned at late night, which bases on the evidence informed in the schematic design. Overall, the holistic lighting strategy for the elevated bridge is successfully supported and implemented by this adaptive lighting setting.

3. Summary

Along with the rapid rise of ALAN applied in outdoor space, and the increasing evidence about its adverse effects as light pollution, exterior lighting design need to take a more holistic approach to mitigate the gap between research and practice, to achieve a more sustainable lit environment at night. The exterior lighting for Ningbo Academician Center is taken as a pilot to practice a new methodology, which is developed under a proposed holistic exterior lighting

design framework and integrated quantitative and qualitative methods with evidence-based method. Since exterior lighting design needs to address more and more complicated issues and respond to the everchanging environment, adaptive lighting strategy and intelligent lighting system can be leveraged as an important tool in exterior lighting practice.

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