The Development of Task-ambient Lighting Strategies for Office Buildings in Thailand

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ABSTRACT

This paper presents the ongoing development of task-ambient lighting strategies designed to achieve deep energy savings and quality lighting for office buildings in Thailand. To achieve these, in-depth interviews with key stakeholders, field surveys in offices with task-ambient lighting, and market search as well as usability testing of available products were carried out. Design criteria and main product attributes that address key barriers and the stakeholder's concerns were identified; three new prototypes were developed. Subsequently, a pilot study was conducted to observe users' interaction with adjustable feature of the prototypes and overall satisfaction of lighting performance. Based on the pilot study the prototype was adjusted to improve the lighting performance, while solving visual discomfort and reflective glare. To evaluate the energy saving potentials and users' satisfaction of the new prototype, an experimental study in a full-scaled test office with 80 participants was planned. Three task-ambient lighting scenarios will be compared to a base case of the uniform lighting. Lighting simulations suggested that the proposed task-ambient lighting with added vertical illuminance could save up to 40 to 60% of electricity. It was also hypothesized that a provisional of personal control could save even more energy and provide higher user's satisfaction.

Keywords: Task-ambient Lighting, Office Lighting, Prototype Development, Personal Control

INTRODUCTION

In commercial buildings lighting accounts for 25% of the overall electricity use. Typically office spaces rely on ceiling-mounted luminaires for both task and ambient lighting requirements. This practice results in high light levels being provided throughout the workplace i.e., even in non-task areas. Separating task and ambient lighting systems can result in significant energy savings by reducing the ambient light levels, and providing supplementary task illuminance where it is needed. Past research (Yamakawa et al., 2000; Newsham et al, 2005; Nincharoen et.al., 2009; Gene-Harn et al., 2016) have reported that task-ambient lighting approaches could save up to 20-50% of electricity use compared to the conventional general lighting.

The research studies in California (California Energy Commission, 2010a, 2010b; HMG, 2009) with task ambient lighting systems demonstrated a number of key advantages. Firstly the studies indicated 30 to 50% energy savings potential and reduced demand charges in both retrofit and new design approach. The integration of occupancy sensors to control the individual task lights provided an additional saving during periods of vacancy. Separating the task and ambient component also allows for dynamic controls to be applied on the ambient lighting such as daylighting and demand response to be easily implemented. Reducing the intensity of the overhead lighting results in a reduction in both direct glare from ceiling luminaires as well as reflected glare from specular surfaces.

In Thailand, Nincharoen, Chuntamara and Siminovitch (2009) reported on the experimental study in a full-scaled mock up office that aimed to investigate users' acceptance of task-ambient lighting in Thailand. Forty-eight subjects performed paper-based and screen-based tasks under four lighting conditions.

The result indicated that the participants preferred the lighting condition with the ambient illuminance of 300 lux with additional cove lights and task lights, consuming 7 W/m^2 or 50% lower than the current building codes. The result was in line with previous research (Boyce et al., 2006) that recommended the provision of added illuminance to compensate for the reduced ambient light which may lead to dissatisfaction. Despite the users' acceptance and potential benefits, the adoption rate of task-ambient lighting in Thailand has been very slow and not widely used.

There are some 10,000,000 m^2 of commercial office space in Bangkok Metropolitan areas, and retrofitting these spaces with task ambient approaches would significantly reduce the country's growing peak demand. Thus the goal of this study is to accelerate the adoption of task-ambient lighting approaches in Thailand. Specific objectives of this phase of the study include 1) identifying the social mechanism involving task-ambient lighting; 2) understanding key barriers and stakeholders' concerns; and 3) developing and evaluating prototype of task-ambient lighting systems that are suitable for a wider adoption in Thai context.

METHODS

Since the task-ambient lighting approach is a relatively new concept in Thailand, methods used in this study were based on a theoretical framework from the *Diffusion of Innovations* by E.M. Rogers (1962). Each method is described below:

1. In-depth interviews

In-depth interviews of key stakeholders who were involved in office building projects, particularly the ones with task-ambient lighting systems, were conducted. Key stakeholders being interviewed included 9 representatives of owners and facility managers, 18 interior designers and lighting consultants as well as 2 green building consultants (LEED AP). In addition, 3 lighting and 3 office furniture manufacturers and suppliers participated in the interviews. The questions covered three themes: 1) real or perceived advantages of task-ambient lighting compared to general lighting approaches 2) communicating the concept of task-ambient lighting to the client and 3) barriers and challenges of designing, specifying and/or supplying task-ambient lighting products.

2. Field Surveys

Field surveys were carried out in three offices, two of which located in LEED certified buildings. In all cases, side windows and ceiling mounted luminaires provided ambient light. Desk-integrated LED task lights were provided to add required task illuminance for each occupant. While interviews with facility managers, owner representatives and some office workers were conducted in three buildings, photographic records, photometric measurements and questionnaire surveys were carried out in only one office due to the approval from the owner. The detailed surveys in office C were carried out on the fourth floor where 40 permanent staff occupy the open-plan office (Figure 1). The ambient light was provided by daylight as well as by suspended up and down luminaires.

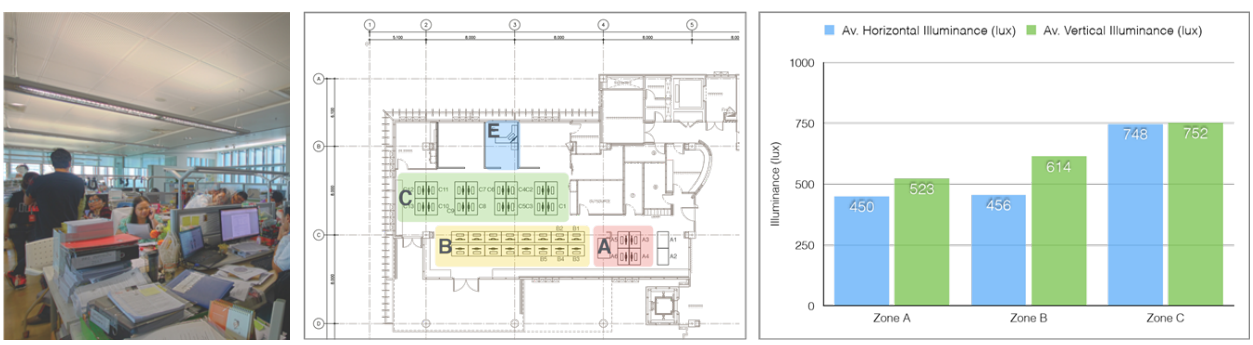

Figure 1. Photometric measurements in the open-plan office with task-ambient light

Task lights were LED integrated with partitions at approx. 60 cm. above the work plane. Light distributions on the horizontal and vertical task planes were measured using the Konica-Minolta T-10 illuminance meters. A questionnaire was translated into Thai and modified from the Office Lighting Survey (Eklund and Boyce, 1995).

3. Developing Prototypes and a Pilot Study

The results from the market research and product usability testing were combined with the desirable product characteristics learned from the interviews and field surveys. Design criteria for appropriate task-ambient lighting systems for Thai context were identified. Conceptual designs were generated using a software Solid Work and initial prototypes were made to test lighting performance and visual comfort. Subsequently three designs were selected and developed into working prototypes with adjustable arms and light levels.

A pilot study was then carried out to evaluate and refine the design; 16 volunteers aged between 24-47 years old participated. The test room was a single office (4m*4m*3m) with the ambient light (approx. 260 lux) provided by two suspended T5 (4000K) fluorescent luminaires. A desk had matt white top and 35 cm. high mid-grey partition with the reflectance of 75% and 38% respectively. Two prototypes were tested and each was fitted with a module of 3W dimmable linear Nichia cool-white LED (4000K). The first prototype has horizontal pivotal point, while the second one can be adjusted in the way that light is always parallel to the horizontal task plane.

To monitor preferred light distributions adjusted by the participants, a VDO camera (GoPro Hero 5) was mounted above the desk and recorded changing light patterns on the test area (Figure 2). Each participant was asked to freely use and adjust each task light. Afterwards the researcher interviewed them regarding their preference of personal control of lighting, overall satisfaction and experiences of using each task light, compared to the general lighting they have at their own office. Results provided an insight of how the users may interact with adjustable features and personal control of task-ambient systems.

Figure 2. Prototypes (left) and top views from the pilot study

RESULTS

Information collected from the in-depth interviews and field surveys provided a better understanding on the current situation and role of stakeholders involving in the provision of task-ambient lighting for offices in Thailand. Key drivers for using task-ambient lighting were energy savings and providing individual controls in order to get green building rating certification (e.g. LEED). Thus the main motivation is to support the company image and commitment on corporate social responsibility (CSR). Despite a growing number of green office buildings, a small number of projects engaged lighting consultants and considered the task-ambient lighting approaches.

Key barriers included the lack of knowledge about the design principles of task-ambient lighting among the building professionals and suppliers; the lack of confidence among the decision-makers and facility managers. Furthermore, there is a lack of reliable and good performance task lights with acceptable additional costs. In terms of policies, attractive incentives from the government efficiency programs are also needed. Few success cases may also contribute to the slow adoption rate. According to the field surveys in three offices, only one of them (shown in Figure 1) has implemented it successfully. In this case the organization could save some 30% of lighting energy and 90% of the occupant seemed to be satisfied with the quality of lighting and overall working environment.

Similar to the measurements obtained from the field surveys, the participants in the pilot study also preferred to have light distributed evenly over the horizontal task areas as well as on the partition in the background. For personal control of lighting, while most of them would appreciate some levels of control, they do not want to figure out the appropriate lighting conditions by themselves. These have led to the design decision to use three of 30cm LED modules in order to deliver wider light distribution; at the same time, some adjustable features were reduced to be more user-friendly and for easy maintenance. A novel feature was also added to minimize problems associated with glare on computer screens - the middle LED module of the task light can be adjusted and dimmed separately.

FURTHER STUDY

Figure 3. Lighting simulation of the experimental room

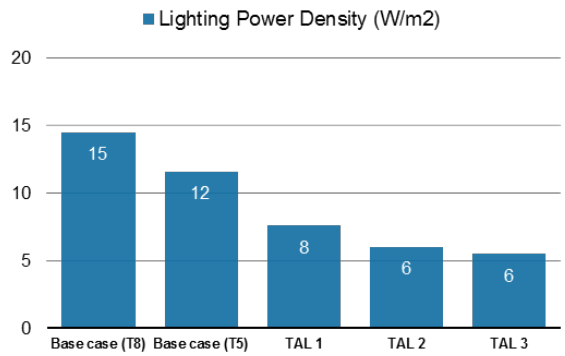

Figure 4. Lighting power density of the test cases

Currently an experimental study was designed and planned to evaluate the energy saving potentials and users' satisfaction of the proposed three task-ambient lighting strategies. Independent variables are types of the ambient lighting and additional vertical illuminance. The experimental room is a full-scale open plan office with 8 workstations furnished in neutral colour (Figure 3). Using the lighting simulation software DIALUX, the comparison of lighting power density consumed by each condition is shown in Figure 4. To represent the multi-generation workforce, 80 participants with two age-groups (younger and older than 45 years old) will take part in the study; each will perform visual tasks under four lighting conditions which will be randomly presented to them. Subsequently, the participant will complete two sets of questionnaire regarding their subjective perceptions, preferences and experiences with personal controls. It was hypothesized that the proposed prototype of task light with the direct-indirect ambient light and additional vertical lighting will be preferred and result in deeper savings.

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