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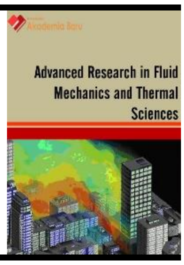

Assessment of Energy Saving Potential and Lighting System in Teaching Building

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Mariah Awang[1,*], Tham C.S[1], Nurhanis Mohd Basir Ruddin[1], Mohamad Ashraf Abdul Rahman[1], Nuramidah Hamidon[1], Faridahanim Ahmad[3], Kamaruzaman Musa[1], Sasitharan Nagapan[1], Mohd Shahril Abdul Rahman[4]

[1] Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Muar, Johor, Malaysia
[2] Faculty of Civil and Environment Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia
[3] Department of Civil Engineering,Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
[4] Department of Real Estate, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

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ABSTRACT

Energy consumption and the potential for energy savings had become more intensive in public buildings in order to improve energy performance. This case study was identified the current occupancy, lighting use patterns and lighting performance in G3 Block B teaching building where most of the teaching rooms were located in University Tun Hussein Onn Malaysia. In order to determine the energy saving potential and strategies for lighting system in the building, a series of data collection were conducted to the effects of occupancy and lighting use patterns to display the lighting energy consumption and lighting energy waste of the case study building. The findings of this study displayed lighting use patterns varied among all the investigated lecture rooms at which 31% of lighting load was wasted and 13% of lighting load misused by the building users were recorded. Moreover, the result of lighting performance of the lecture room obtained was met the recommended average illuminance level (300-500 lux) of lighting for working interiors as classroom in MS 1525:2007. In addition, the perception, awareness and practices of energy conservation behavior on lighting of the building user were also studied through structured questionnaire. With regard to the findings of questionnaire in this study, the responses indicated that most of the respondents agreed they were at good perception, awareness and practices on their energy conservation behavior on lighting. Based on the various data obtained in this project, the energy and cost saving potential strategies were suggested for instances the structural energy conservation measures and non-structural energy conservation measures to improve the usage and efficiency of the lighting system in the teaching building towards energy conservation.

* *Corresponding author.*
E-mail address: mariah@uthm.edu.my (Mariah Awang)

1. Introduction

International Facility Management Association defines facility management as a multi-disciplinary profession that intergrading people, place, process and technology to ensure the functionality of the built environment. The key function of facility management is integrated and managing all the available facilities and support services to support its core businesses in both long and short run [16]. The intention of facility management is to provide an effective and quality environment on cost effective basis (with least resources) in order to enhance organizational effectiveness [17]. Here, facility management professionals play a vital role in providing quality and high performance facilities [18]. At present, the world is afflicted by the critical energy problems, including depletion of energy resources, energy security, climate change as well as degradation of environment quality. In preserving the global sustainability, the major challenge is derived from energy sustainability where the ever-rising energy demand must be reduced [7]. To ensure the facility efficiency, energy performance especially energy cost is one of the major areas to be observed and monitored closely.

Energy consumption and the potential for energy savings become more intensive in residential, industrial, commercial and public buildings to improve energy performance nowadays. Energy consumption is growing as construction booms, particularly in countries such as China and India [1]. Others, energy supply also plays important issue needs to be constantly organized in order to maintain the demand in future [19]. According to Haw *et al.,* [2], one of national energy policy's objectives in Malaysia is to promote efficient utilization of energy and the elimination of wasteful and nonproductive patterns of energy consumption. In any organization, electricity usage should be analyzed to identify unwanted and unnecessary usage, which would create the opportunities to find waste and initiate solutions to reduce it. Investing and implementing energy saving practices, energy management and conservation will greatly contribute toward reduction in electricity cost but more importantly use the electrical energy in the most diligent way and reduce wastage in energy use. Figure 1 shows the operation and building maintenance in public university.

Lighting is one of the largest users of electrical energy in a typical commercial building [14] that accounts for 5– 15% of the total electric energy consumption [13]. Lighting is a key issue in minimizing overall energy consumption of building and energy consumption of a lighting installation is strongly dependent on lighting controls usually related to daylight and occupancy detection [4]. In both new and old buildings today, there are countless opportunities and various energy-efficient lighting technologies that are introduced to improve lighting efficiency and to minimize the cost of energy used.

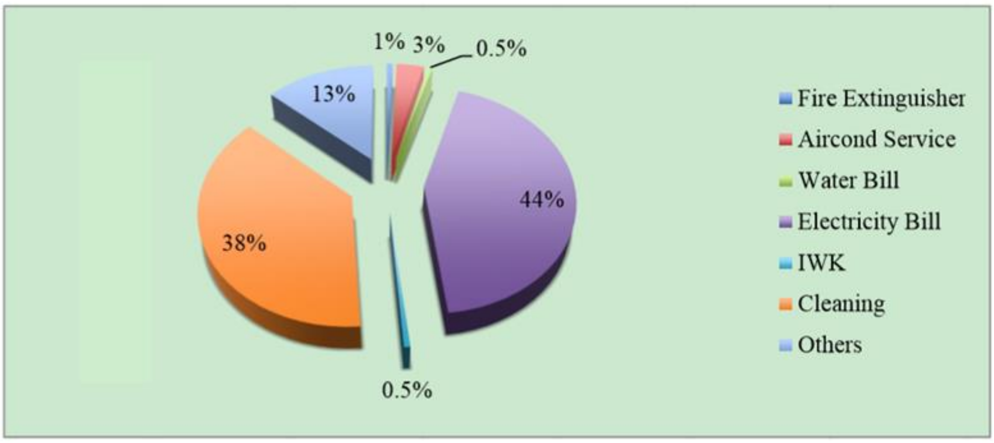

Fig. 1. Operation and building maintenance in public university [6]

Occupancy presence and behavior in buildings has shown to have large impacts on energy consumption of lighting and space appliances such as heating, cooling and ventilation demand, and building controls [5]. The irresponsible behavior can add one-third to a building's designed energy performance, while conservation behavior can save a third.

Many researchers have studied and reported the significance of adopt energy-use behavior. Principally, Ting [7] stated non-structural energy conservation approach by improving user's behavior can be incorporated to reduce energy demand and achieve energy sustainability. For instance, consumer behavior is one of the most important issues with respect to household energy consumption [8].

According to Delzendeh *et al.,* [9], all occupants in the building are contribute and responsible for the increases in overall energy consumption. Thus, reduction in energy consumption should be a common responsibility to every occupant subsequently. A study also stated that human behavior plays an integral role in energy conservation activities by which a potential of energy and cost saving can be achieved by approximately 10 % if building users can be persuaded to more energy conserving [10].

University is the place where the occupants consume a substantial amount of energy. Nowadays the higher probability of energy wastage is mainly caused by the user's negative energy use behavior in a building [7]. Increased electrical energy usage in University Tun Hussein Onn Malaysia every year that ends up with huge cost of electricity bill was due to the rapid growth of the university's activity [11]. The teaching rooms were involved in this study since they consume the greatest item of energy, comfort and well-being of students which are the main objectives pursued in educational environment.

It is normal to observe that building users do not diligently turn lights off when they vacated spaces, with the lighting system in an empty classroom. Consciousness and intention of building users are not strong and causing unnecessary wastage of energy consumption to a building. Thus, this produces the opportunity to analyze the energy usage of teaching room and identify the potential energy reduction and cost savings. Moreover, there is great need to promote intention of user's behavior change to ensure they switched off the electric loads when the users were out of the room. Users usually turn on the wall switch lights, which need manual controlled, as they enter the room, but not usual turned off as they vacate. Users may not hesitate and unwilling to turn off lights in a small room if they think someone else may still be in the space or enter again shortly. If those students do not turn off the lights when they leave for the day the organization winds up consuming power for example 100 unnecessary lights for 3 hours each day. Then, the 36-watt fluorescent light left on for an additional 3 hours each day burns up RM3.94 of electricity per day or RM118.26 per month at 36.5 cents/kWh.

Based on the pilot study that has been conducted in this study, the researcher can observe there are 36% - 46% of the total hour usage of lighting system are needlessly in the unoccupied lecture rooms. Thus, it was crucial to analyze the energy usage of lighting system in teaching building for identification of potential energy reduction and cost savings. Apart from that, the intention of user's behavior towards energy conservation can be done by raising the energy awareness and improve energy-use behavior among the students by their behavioral improvement [12].

2. Methodology

There were appropriate methodology processes in the direction of achieving the objectives of this study. In order to achieve this study, several procedures to conduct the study have been selected as shown in the overview of methodology process in Figure 2.

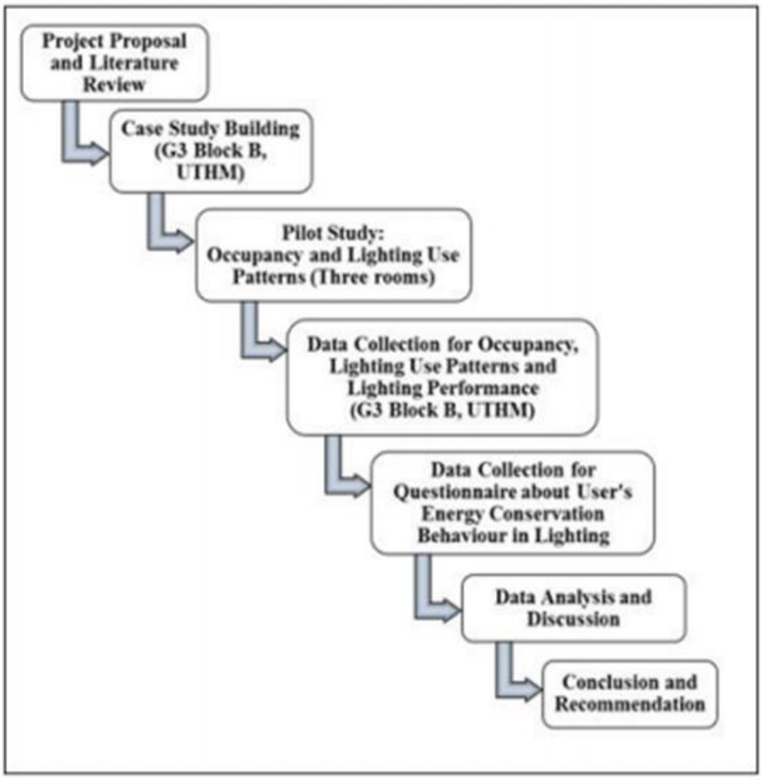

Fig. 2. The overview of methodology process

2.1 Case Study Building

This project was based on a case study of the occupancy, lighting use patterns and lighting performance of lighting system in G3 building Block B, UTHM to know the energy potential of the building. G3 building located at the center of the university and constructed various type of teaching rooms and lecture halls with teaching facility. Thus, this teaching building was selected to be studied due to its high usage of teaching rooms by the users. The selection of case study building was determined by the following factors.

i. This teaching building consists of the most amounts of teaching rooms in the campus.
ii. The existing lighting control system of this building is manually controlled by the users.
iii. This building is free access by the users in the building operating hours resulting the users of the rooms are intermittent and unpredictable.

2.2 Case Study Building

This study presented the analysis on the data of lighting usage and occupancy for a two-week monitoring period between March and October in 2016. The purposes were to determine and understand the energy usage pattern of the lighting system based on the occupancy data and amount of lighting operation data in the rooms for study.

Data for twelve rooms were originally collected for the monitoring period, start at 8.00a.m to 6.00p.m every day in the weekdays. The rooms for study included BP1, BP2 and BK-B1 until BK-B8. The total lighting load or amount of lighting operated in the room and the status of occupancy were observed and recorded in every 30 minutes into a data collection form. Due to the limitation of measurement equipment in the faculty and university, direct observation and manual data collection were chosen to conduct the data collection in this study.

An occupancy pattern is the information of condition for people enter or leaves the building from the start and end of daily occupancy in the building. Besides, lighting use patterns is the measure of status of lighting used during the building operation hours in the lighting zone [13]. According to the previous study [14], the condition of occupancy and lighting use patterns were observed to analyze and determine the basic energy savings potential. Lighting and occupancy use in any space will usually categorize into one of the following four conditions as shown in Table 1.

Table 1
Types of data required for occupancy condition

Condition	Description
1	Occupied with the lights on
2	Occupied with the lights off
3	Unoccupied with the lights on
4	Unoccupied with the lights off

Meanwhile, Table 2 showed the status of occupancy. It was categorized into another three-occupancy status, namely 'CLASS', 'EMPTY' and 'MISUSE'. The collection of status of occupancy data eases up the analysis of total hour usage and energy use of lighting system. Status of 'CLASS' was meant to the room was occupied and used for attending a class or teaching and learning activities. 'EMPTY' is meant to the room is unoccupied by any building user.

Table 2
Types of data required for status of occupancy

Status	Description
CLASS	Room is occupied for class with lights on or off
EMPTY	Room is unoccupied with lights on or off
MISUSE	Room is occupied with unnecessary lights on or off

As mentioned, there was a specific condition that was emphasized in this study, which was the 'MISUSE' status. The building users sometimes misused the lighting for the activities that switch on the excessive and unnecessary number of lighting in the room. For example, one or two users in the room were switched on the entire lighting for the activities like resting or discussion which excessive lighting operation can be avoided. These statuses of condition were observed for the aid of determining the influence and awareness of the user behavior towards energy conservation.

2.3 Lighting Performance

The basic requirement for adequate lighting is that the work must be easy to see and the light comfortable to the eyes. To investigate the lighting performance, the illuminance level of daylighting and artificial lighting installed in the room were measured and analyzed. The lighting performance was then determined whether meeting the comfortable illuminance levels and MS 1525:2007 recommended average illuminance of lighting for working interiors [15].

Lux meter was used to measure internal illuminance in this study. Firstly, the internal area or dimension of the room for study was measured and recorded. The floor area was used to determine the necessary number of points needed to obtain an accurate measured average illuminance. To measure the illuminance level of the rooms, the methods to conduct the illuminance measurement explained in the CIBSE [16] were applied in this project. The data of average illuminance level obtained in this study were recorded and analyzed to determine the energy saving potential and strategies for the lighting system in the building.

3. Results

3.1 Building Description

In the direction to achieve the first objective in this study, direct observation and various sets of data collection were conducted to determine the energy saving potential and strategies for lighting system in the building. First and foremost, the selected building located in main campus of UTHM, Parit Raja, Batu Pahat, Johor, at 2° toward North and 103° toward East. The blocks are three stories building with 12 lecture rooms and designed to house 960 people for a teaching building at one time. Class hour normally starts at 8.00 am and ends at 6.00 pm, 10 operating hours.

Table 3 shows the details of the teaching building characteristics and lighting equipment that are used in the teaching building. This information was used to analyze the current usage of energy for lighting to identify the unnecessary lighting used and wastage. Throughout the direct observation to the building, the lighting system in this building was mainly utilizing the fluorescent lighting and CFL downlight. In this study, the lighting system of lecture rooms were focused due to it were represented the most wastage of electricity on unnecessary lighting consumption. The lecture room's lighting system were designed to be controlled by manual switches thus it is causing some irresponsible building users used excessive lighting that can be reduced or avoided, and they did not switch off the lights after they vacated.

Table 3
The lighting equipment that are used in the teaching building

Lighting System of G3 Block B Building, UTHM		
Men and Women Toilet		6 units
Lighting type	Quantity	Power rating, Watts (W)
CFL Downlight	24	18
Handicap Toilet		6 units
Lighting type	Quantity	Power rating, Watts (W)
CFL Downlight	6	8
Lecturer Room		12 units
Lighting type	Quantity	Power rating, Watts (W)
CFL Downlight	36	18
T8 Fluorescent Lamp	432	36
Corridor Lighting		
Lighting type	Quantity	Power rating, Watts (W)
CFL Downlight	31	18
Staircase Lighting		
Lighting type	Quantity	Power rating, Watts (W)
T8 Fluorescent Lamp	28	18

The ground floor and first floor lecture rooms were also installed with two additional downlights at the front of the rooms. Due to the lack of maintenance, the downlights mostly were unable to light up. Thus, the number of downlights operated in the room was not recorded in this study. Moreover, the staircase lighting with fluorescent lighting was also showed unnecessary usage in the daytime due to the ineffective three-way manual light switch. The corridor lighting in each floor was controlled by the photocell sensor which exterior lighting would be automatically turned off when sufficient daylight is available in the daytime. There are only few corridor downlights were designed to be manual controlled by the building user such as the area near to toilets. Meanwhile, the lighting systems of toilets were also displayed unwanted wastage of lighting, which the lights were switched on all the time even the toilet was empty. The lighting system of the other rooms in the building for instance the utility rooms, janitor rooms, control rooms, electric rooms and ICT rooms were not involved in this study because of they are not accessible to the students, the lights would not switched on all the time and consumed very less lighting usage throughout the year.

3.2 Occupancy and Lighting Use Data

According to Figure 3, lighting use patterns varied among all the investigated lecture rooms. Among the lecture rooms, the occupants recorded 42.53% to 69.97% of lighting use for the teaching and learning purpose. The energy saving potential from unnecessary lighting in empty room was recorded from 15.18% to 42.53%. This indicated the lecturer rooms were light on in an unoccupied space due to the building users not turn off the light when they vacated the room. In the meantime, there was also 9.01% to 14.93% of lighting energy misuse in the investigated lecture rooms.

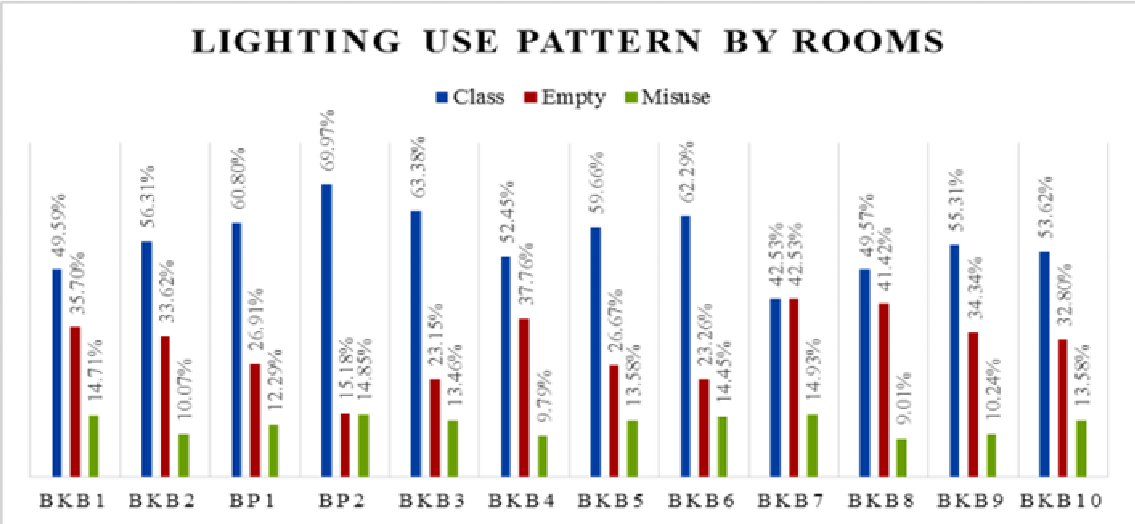

Fig. 3. Lighting use pattern according to lecture rooms

Figure 4 summarize the total lighting load or amount of electricity operated that were obtained in all 12-lecture rooms that studied during the monitoring period. There were recorded 56% or 35.451kWh of energy cost spent to light up the class for building users to attend lectures and other activities. 31% or 19.385kWh of lighting load was unnecessary which the energy cost can be saved, and the building users misused 13% or 7.91kWh of lighting load.

According to Figure 5, there were 61% conditions of occupancy that building users occupied the lecture room with the lights on. Then, there were only 3% conditions of building users occupied with the lights off. The data shown for condition 2 indicates that building user rarely occupied spaces with the lights off, indicating that for the lecture room may be a small potential benefit of installing manual controls. Moreover, there were 25% in condition 3 which indicated the wasted lighting energy of the lecture rooms were unoccupied with the lights on. These reflected that the occupants to utilize the lighting system not effectively and not efficiently used the existing manual lighting control devices. At last, the most satisfied situations were only recorded as 11%, which the lights were off when the room was unoccupied throughout the monitoring period.

In summary, the finding of this part of study was the occupants did not efficiently use the existing installations of lighting system in the building. Building users tend to turn habitually on lighting as they first enter a lecture room and keep the lighting on until they leave the space. The building users especially the students had no intention to conserve the needlessly lighting in the unoccupied space or minimizing the overhead light as necessary in the lecture room. The energy conservation measures for instances installation of automatic light switching like occupancy sensor or energy saving lighting fixtures might become the energy and cost saving potential of lighting system in the teaching building.

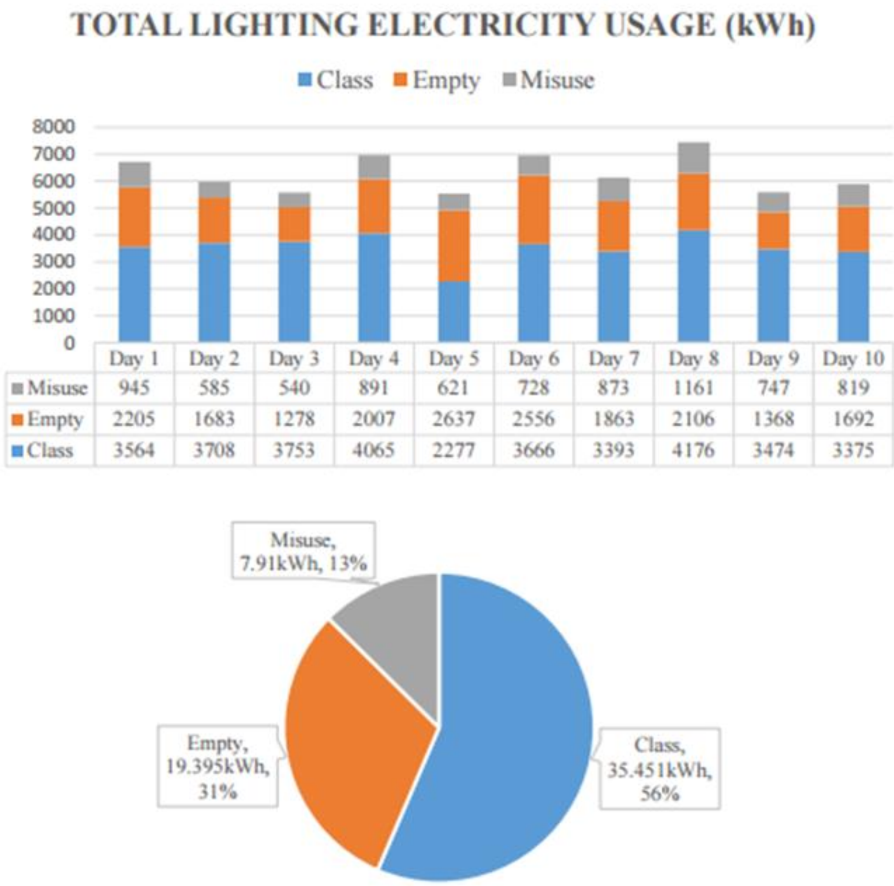

Fig. 4. The total lighting electricity usage of 12 lectures rooms in two-week monitoring period

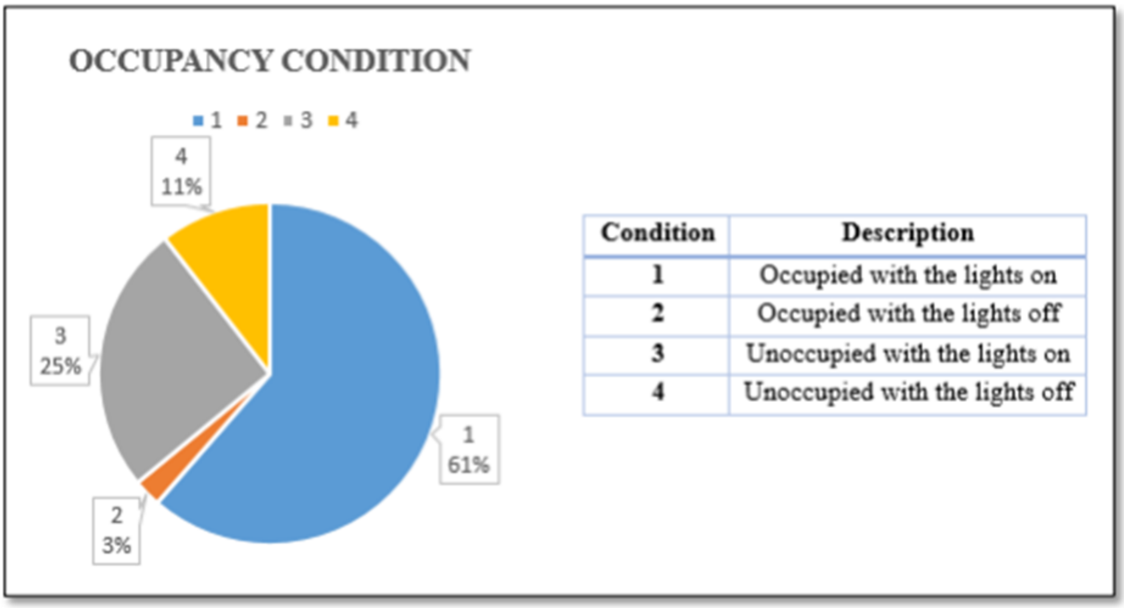

Fig. 5. The occupancy condition in the lecture rooms during monitoring period

3.3 Lighting Performance

The data of lighting performance obtained through the illuminance measurement conducted in the lecture room also described the space was actually light up by artificial lighting with comfortable illuminance levels for the building user to occupy the room and interior works. The lecture room, BK4 was chosen to measure the lighting performance due to it is located in the middle of the building. All lecture rooms in this building were same functional to provide a space mostly for teaching and learning purpose. There were all approximately constructed in same orientation, floor area, location of windows, space allocation for furniture and designed with equal amount of lighting system. Thus, the lighting performance of the studied room can represent the actual value of other rooms.

Based on the illuminance measurement of daylighting in the lecture room as shown in Figure 6, the result showed that the space was not lighted up evenly by the natural lighting from the windows.

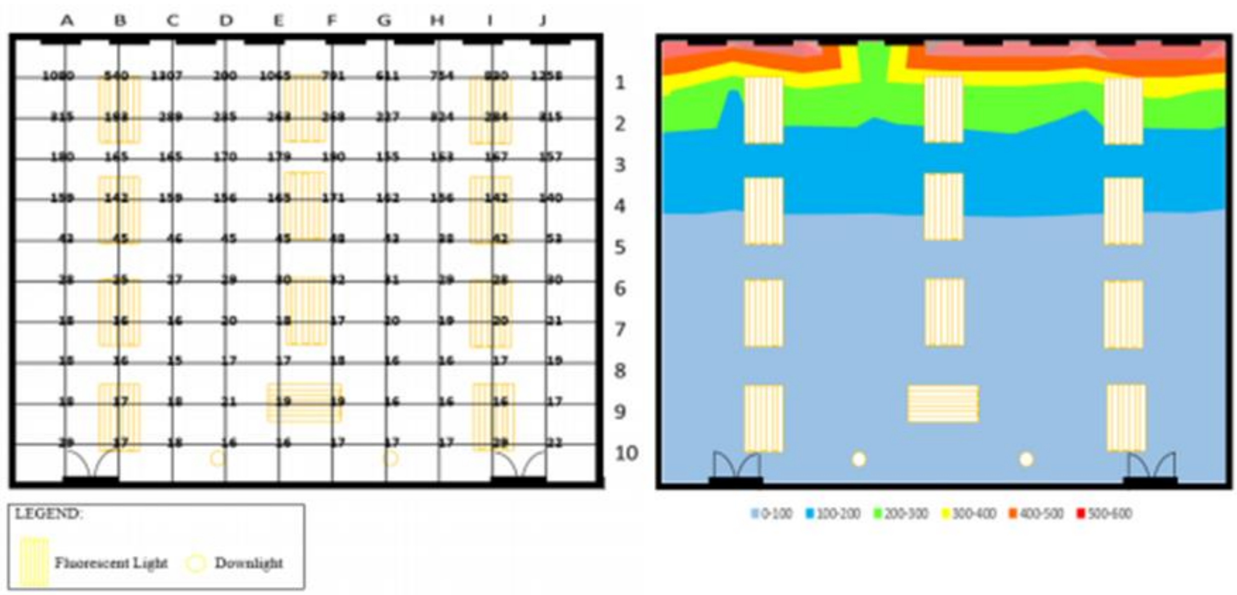

Fig. 6. The illuminance (lux) and illuminance contour of daylighting into the lecture room

These were due to the building façade and space allocations in the lecture room were not designed to utilize daylighting fully into the internal space. Thus, artificial lighting became essential for internal lighting system. Meanwhile, the result obtained for artificial lighting was met the 300-500 lux, recommended average illuminance level of lighting for working interiors as classroom in MS 1525:2007 as shown in Figure 7. These meant that the lighting system in the lecture room was designed and utilized effectively to provide an adequate illuminance levels for the building user to occupy the room and interior works. Thus, the replacement of the existing lighting system into more energy efficient lamp fittings would possibly become the energy saving potential to reduce the cost of operation for lighting system in the building.

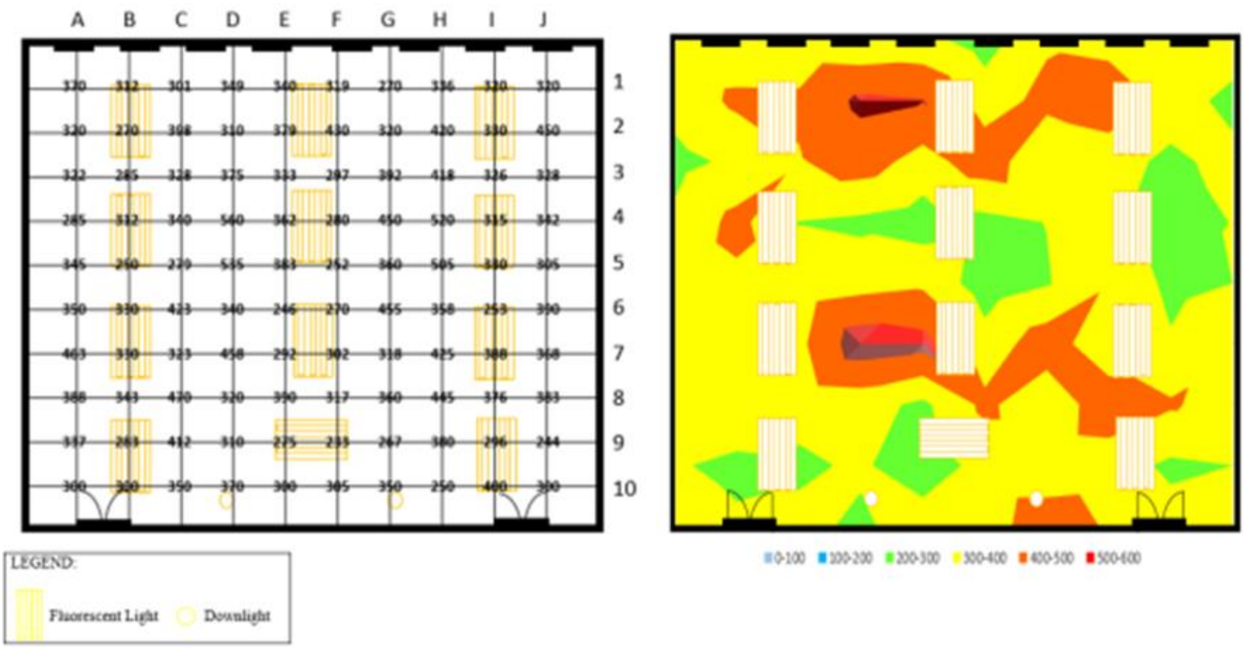

Fig. 7. The illuminance (lux) and illuminance contour of artificial lighting in the lecture room

4. Conclusions

This paper reported field survey results on occupancy, lighting use patterns and illuminance distributions in the case study building to achieve the first and second objectives of this study which were the identification of the cost and energy saving potential of lighting system in the teaching building and the effects of occupancy, lighting use patterns and lighting performance on lighting energy consumption.

The findings in this study showed the lighting use patterns were significantly related to the occupancy patterns of the investigated lecture room and the building user's behavior. There was a strong tendency of turning on lighting on occupants' first arrival in the morning and of keeping the lighting on. Thus, it was crucial to understand when and how the occupants use lighting. This study resulted that almost half (44%) of lighting use in the investigated lecture room were wasted (31%) and misused (13%) by the building user. The behavioral patterns for lighting that were revealed in field studies and found that the occupants did not consider indoor daylight availability and keep the lighting systems on throughout the duration they occupied for any activities. They were also not aware to minimize the overhead lights based on the space that needed to light up for indoor activities and the moment that lighting was not necessary such as in an unoccupied space.

Conclusively, there were large energy saving potentials of lighting system in the investigated teaching building resulted from this study. The data also indicated that the design of building and lighting systems and the building user's energy conservation behavior in lighting are closely associated with lighting energy demands, for instances the building orientation, space allocation and internal illuminance measurement of natural daylighting and artificial lighting. Thus, changes in building user's behavior can contribute positively to the University for reducing their energy usage and costs.

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