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ENHANCING ENERGY EFFICIENCY: A CASE STUDY OF LIGHTING RETROFIT SYSTEMS IN MALAYSIAN UNIVERSITY ENVIRONMENTS

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Abstract. *With an enormous potential for demand reduction, lighting is one of the main variables influencing demand of electricity in the building energy industry. In this work, laboratory lighting systems for a Malaysian university are used as a case study to discuss the challenges of designing an efficient lighting system for educational spaces. Experimental results indicate that the university laboratories receive more than 300 lux of light from the present lighting system and natural light during the day, under clear, average, cloudy, and night circumstances, respectively, for instructional purposes. The illuminance requirement is exceeded by the presently installed lighting system. This exceeding illuminance level was discovered to be mostly caused by the excessive amount of installed light. Based on simulation results, it is possible to save a significant amount of energy, money, and greenhouse gas emissions by installing well-arranged light emitting diode (LED) tube lights with a 0.8 maintenance factor.*

Key words: *Lighting system design, Light retrofitting, Energy saving, Lighting energy demand*

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1. INTRODUCTION

Lighting is one of the energies that enhances human eyesight, which includes both artificial light sources like lamps and daylight entering a space naturally [1]. The country development and population growth are both driving the demand for illumination in the modern era. The purpose of interior lighting is to protect people's health, safety, and comfort while they go about their everyday lives. Generally, artificial and natural light are the two main categories of lighting. However, the majority of building inhabitants choose artificial illumination as their preferred alternative nowadays. Indoor illumination plays a crucial role in the evaluation of Indoor Environment Quality (IEQ). Indoor Environment Quality was implemented to create a suitable interior atmosphere that promotes the comfort, health, and well-being of the occupants. IEQ was stated in terms of how environmental factors, such as air quality, thermal comfort, lighting quality, and acoustical quality, affect occupant health. When measuring IEQ, one of the most important factors that shouldn't be disregarded is lighting quality. Furthermore, in the case of non-residential buildings like educational buildings in higher education institutions, the components related to Indoor Environmental Quality (IEQ) accounted for 21% of the criteria utilized in evaluating green buildings. However, IEQ is never given top attention in the majority of management and development plans [2].

Everyone spend most of their time inside, whether at work, school, or in their homes, and it is true that indoor environments have an impact on people's performance, health, and general well-being [3, 4]. As highlighted by [5], people spend more than 80% of their daily hours inside the building as opposed to outside. Due to a variety of activities, including working, learning, and relaxing, building occupants are spending greater time within the building [6]. Effective lighting improves occupant welfare, health, and safety by reducing total energy consumption and providing psychological and physiological advantages. For this reason, the best possible interior illumination should be maintained. Insufficient illumination has a direct impact on occupants' health and performances [7, 8]. According to [7], the health of the occupants will be impacted by excessive illumination, which can lead to eye strain, migraines, exhaustion, eye pain, and continuous headaches.

The mission of Malaysia's higher education institutions is to improve the quality of life on campus by reducing their environmental impact. A conducive learning environment is necessary. Ensuring the health and comfort of building occupants through suitable lighting is a crucial aspect of creating a conducive atmosphere. Students might become more focused in a welcoming and supportive learning atmosphere. Lighting is crucial, because excellent lighting may increase occupants' perceptions of safety and preference [9]. In order to provide the required facilities for the learning area, such as increasing student productivity, increasing the effectiveness of instructions, and sharpening attention throughout the learning process, indoor lighting in academic buildings is crucial [10]. Most of the time, students will be indoors, whether in the lecture hall, library or dormitory. Thus, in order to facilitate learning, it is always necessary to provide a comfortable interior atmosphere for the students. The building operator bears the responsibility of guaranteeing optimal interior light levels that facilitate students' learning.

Prior research has demonstrated that the interior environment quality and the buildings themselves are in a poor and unsatisfactory state with respect to illumination. For instance, a research conducted by [11] evaluated the IEQ and productivity of the occupants of the 10-story office structure Council House 2 structure (CH2) in Melbourne. The results indicated that the respondents were dissatisfied with the lighting at their office since it was documented to have less than 320 lux, which is below the required amount. A further study was carried out by [12] to evaluate the illumination in the National University of Malaysia's architectural studio. In order to maximize student comfort and eyesight, artificial light is utilized in the architectural studio most of the time. However, the results revealed that the illuminance level was below the required range of 300–400 lux. Students' short-term visual perception will be impacted by such circumstances, and their long-term health will be impacted. Overall, classroom lighting has a significant impact on student performance, behavior, focus, and accomplishment, particularly throughout the learning process, making it crucial for both productivity and student learning [12, 13, 14].

Some earlier research have shown that the amount of illumination in a building is one of the typical problems that affects the health and comfort of its occupants. Previous findings have demonstrated that the illuminance level and lighting did not meet criteria. To illustrate the point, consider the following examples: office buildings [11, 15] and academic buildings [16]. The majority of earlier research on lighting and illuminance was conducted in the setting of homes and workplaces; very few studies were conducted at higher education institutions. However, this study major objective is to outline the constraints, possibilities, and possibilities for energy-saving measures resulting from the efficient lighting system design in a Malaysian institutional building. This study has considered the University Malaysia Pahang Al-Sultan Abdullah (UMPSA), Pekan campus in Malaysia as a case study. More specifically, it takes into account both artificial and natural lighting, as well as several other elements including reflection factors, while designing an effective lighting system for the laboratories of the UMPSA academic buildings.

Several factors make this study unique: This study represents the authors' initial investigation into the potential of establishing a highly effective lighting system for educational institutions in Malaysia. While using Malaysia as a case study, the research conclusions may be applicable to other developed and developing countries. Secondly, the limits of Malaysia's educational lighting system design are shown by this study.

2. Principal of Light and Visual Performance

In the context of the electromagnetic spectrum, the phrase "light" refers to a wide variety of wavelengths, including both visible and invisible light, including gamma rays, microwaves, radio waves, infrared, ultraviolet rays, and X-rays. Light is the crucial element that captures interest in the fields of physics, environmental science, pharmacology, engineering, and industrial design. Light and visual performances in the environment are all strongly interconnected concepts. These inquiries into the overall atmosphere of the building's interior are interpreted in terms of several architectural transformations that began with the early discovery of light. Ibn al-Haythm, known as the Arab Scientist, conducted an experiment on light in the past. He concluded that vision is only possible when a light beam originates from a luminous origin or undergoes reflection from one before reaching the eye [17]. His experiments to demonstrate that light from objects enters our eyes in a straight path and that this is why we can see.

2.1. Illuminance, Absorption, and Fluctuation

The brightness that we perceive is influenced by the light that we see. Luminance is the quantity of light or light that reaches the observer's eyes. In this study, the influence of working plane illuminance on visual performance is the main focus of the illuminance level. When light could be recognized by skin reflections, a connection between humans and light occurred. When light enters the material body and is not reflected at the surface, it will be selectively absorbed and dispersed at wavelengths that give the object its distinctive color through reflection of body. Approximately 95% of the light that penetrates the skin gets absorbed and dispersed within the two layers of the skin, resulting in body reflectance [18]. The theory of light and work performance has demonstrated that task performance is impacted by illuminance [19]. Fluctuations in illumination are identified by observing the effects of both interior and exterior illumination. These variations in light quality will amplify the effect of interior illumination and visibility. When there was a typical light ambiance in the room, the inhabitants were influenced by light fluctuation; however, over time, the real illuminance varied, and the needed level of illuminance could not be maintained. Brightness fluctuation, often referred to as fluctuation, occurs when there is a shift in illumination that appears differently depending on the amount of light present. Their investigation uncovered a change in the experience of visual pain and visual comfort during reading-based actions, as measured by fluctuations in illuminance. Consequently, it resulted in a negative emotional state and a decline in productivity within the professional setting. The primary sources of variation were the outside illumination, the sky, and the architecture of the windows. The effect of sun patches and window sizes, discovering that the latter has little bearing on occupants' moods but that feelings are influenced by sunlight entering windows [20].

2.2. Malaysian Illuminance Measurement Standards

Two types of artificial lighting typically seen in educational institutions are fluorescent and LED lights. The quantity of light that falls upon (illuminating) and splits over a surface is referred to as illumination. Illumination is the measurement of the amount of light flux that is incident on a unit area of a surface being studied. Existing lighting measuring standards provide an indicator for the optimal level of illuminance based on the specific types of spaces. Every nation on the globe has produced a bespoke standard based on its particular climatic and geographical characteristics. An example of this is the establishment of SS531:2006 by the Technical Committee on Lamps and Related Equipment in Singapore, which operates under the jurisdiction of the Electrical and Electronic Standards Committee. The recommended illuminance level for classrooms falls within the range of 300 to 500 lux. In the UK, according to the Code for Interior Lighting, the suggested design illumination for various kinds of classrooms is between 300 and 500 lux. In United States, the Illuminating Engineering Society of North America (IESNA) published a standard of illuminance in the IES handbook that serves as the foundation for lighting design in the country. For a normal classroom, 300–500 lux is the recommended level of illumination. Besides, the GB 50034-2004 Standard, which was issued by the Illuminating Engineering Society of China, specifies the recommended lux level for classroom lighting in Chinese buildings as 300 lux. Then, according to the Japan Illuminating Engineering Society (JIES-008) - Indoor Lighting Standard, classroom lighting in Japan is regulated between 200 and 750 lux, which is somewhat greater than in other countries. The ideal illuminance level for a classroom is between 250 and 300 lux, according to Indonesia's newly approved Indonesian National Standard SNI 03-6197-2000. The Malaysia Standard MS1525:2007 is the name of the lighting measuring standard that is considered to be the standard in Malaysia. An efficiency of energy and alternative energy code of practice known as the Malaysian Standard (MS1525) has been in effect since 2007 for non-residential buildings in Malaysia, with the goal of fostering an environment that is both ecologically benign and conducive to human well-being. Depending on the task, different areas of the building require different levels of interior illumination. To prevent negative impacts on the individuals, in accordance with the lighting supply, the illuminance that is produced by artificial lighting must be in accordance with the standard. For instance, it is recommended to keep the lighting in a classroom between 300 and 500 lux. For a common reading task in typical teaching spaces, MS1525 recommends an illuminance range of 300 to 500 lux, as shown in Table 1. The building administrator refers to this criterion to ensure that the building has an adequate amount of light.

Table 1 Illumination Level Recommendation by MS1525

Learning Space	Standards and Guidelines by MS1525
General Teaching Space	300 – 500 lux
Science Laboratories	300 lux
Library	300 – 500 lux

3. Methodology

The study starts with the assessment of light energy required in two laboratories (Signal Processing Lab, Electronics 1 Lab) of Faculty of Electrical and Electronics Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah (Pekan campus) in Malaysia, to design a retrofitting lighting system. During the system configuration and the system's whole operational life cycle, both aspects must be surveyed and defined as part of the comprehensive

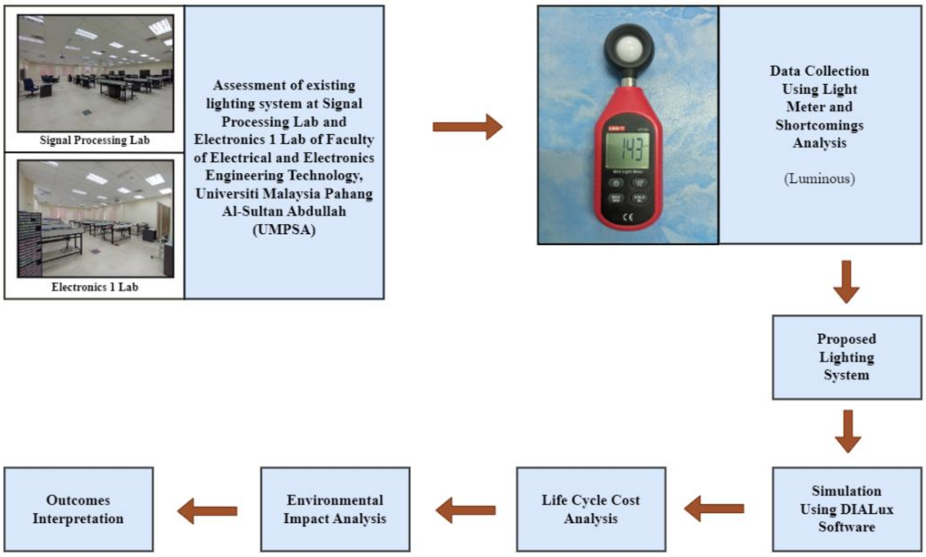


Fig. 1 Comprehensive methodology for light retrofitting at UMPSA

design. Artificial light sources were not used in the daytime measurements. A retrofitting lighting system for the garment was designed using recorded data. Figure 1 shows the complete block diagram of the methodology of the study.

The windows and doors are positioned appropriately. To conduct this investigation, the Luxmeter UNI-T UT383 was utilized to measure the actual Lux in the labs. The measurements included illumination measurement from 0-199999 Lux ± (4%+8), resolution of 1 Lux, and sample rate of 2/s. DIALux evo 12.0 software was used to conduct the simulation concurrently. While there are several lighting simulation programs available (such as BTwin and RELUX), DIALux evo 12.0 software was utilized for simulation purposes as it was shown to be a helpful tool for building an efficient lighting system with the aid of an extensive database [21]. This program is capable of adjusting for both artificial and natural illumination in order to simulate situations. This program for illumination modeling was also utilized in some earlier research such as [22 - 24].

For every sample, measurement processes are nearly instantaneous with a total measurement time of around half an hour. For measurement in the sample, the illumination is nearly constant. A simulation is performed using the resulting values. The luxmeter is utilized to determine lux in these spaces at different points and in different illumination scenarios, such as a clear or overcast sky [25]. As per [26], these illumination circumstances are:

- Clear sky: ‘Brightness in a clear sky change with the sun's azimuth and altitude; it brightens when it gets closer to the sun and reduces when it moves further away from it. The horizon brightness is in the middle of these two extremes.’ The sky is clear of clouds. On October 3, 2023, at 1:00 PM local time, the measurement is taken.
- Overcast sky: ‘The clouds totally cover the sky in this kind of situation, making it difficult to see the sun. There is little to no direct lighting when it is really cloudy, and the diffuse and global illuminance values are quite near.’ We considered an overcast day for these weather circumstances, which is December 25, 2023, at 12.30 PM local time.
- Average/intermediate sky: ‘This kind of sky exists somewhere between overcast and clear sky.’
- That is average weather. The measurement of lux takes place on December 11, 2023, at 1:30 PM local time.
- At night: ‘There isn't any natural light available at this moment.’ At 8:00 PM local time on November 27, 2023, this measurement was made.

Finally, the elements that affect lighting are determined by comparing all of these measured and simulated findings. It should be noted that the above-mentioned dates and hours are only taken into consideration for gathering appropriate measurement samples in a variety of weather and illumination conditions. Table 2 lists the geometric characteristics of both laboratories, while Table 3 lists the lights' technical details with lighting fixtures.

We made use of LED tube light (Philips- LL612X LED31S/830 NB HE) and compared it with fluorescent tube light (TCW060 1xTL-D18W HF) for an efficient lighting system design simulation. Although most lights on Malaysian university campuses are fluorescent tube lights, LEDs are becoming more and more popular these days because of their low energy usage. Table 2 also includes these two lamps comprehensive specifications. The maintenance factor (MF) that we used for all of the artificial lighting simulations was 0.8. The MF is a function of several variables, as shown by Eq. (1). For further information on each of the parameters, see [27].

$$MF = LLD \times LDD \times AFT \times OF \times SVV \times BF \times FSD \qquad (1)$$

Where, MF = Maintenance Factor, LLD = Lamp Lumen Depreciation, LDD = Luminaire Dirt Depreciation, AFT = Ambient Fixture Temperature, OF = Optical Factor, SVV = Supply Voltage Variation, BF = Ballast Factor, FSD = Fixture Surface Depreciation.

The reflectance factor is an additional significant factor in the design of lighting systems. In definition, it is 'the ratio of the flux that a sample surface actually reflects to the flux that a perfect (glossless), perfectly diffuse (Lambertian), fully reflecting standard surface irradiated in the same manner as the sample would reflect into the same reflected-beam geometry.' Generally, it is a measurement of the amount of viewable illumination that may be used when a light source is shining on various surfaces in a room. The simulation determined that, based on surface color, the reflectance factors for the Signal Processing Lab were ceiling 56.1%, walls 60.6%, and floor 61.2%, while for the Electronics 1 Lab, they were ceiling 70.5%, walls 56.4%, and floor 56.4% [28]. It should be noted that the reflectance factors of the surfaces should be carefully selected, since differences in this component will affect the simulation result.

Table 2 Test-room properties

Type	Signal Processing Lab	Electronics 1 Lab
Level	1st Floor	1st Floor
Measurement	Length: 60 feet Width: 56 feet Height: 12 feet	Length: 44 feet Width: 30 feet Height: 12 feet
Fabric	Floor: Cream color tiles Wall: Painted plaster wall Ceiling: Painted concrete ceiling	Floor: Cream color tiles Wall: Painted plaster wall Ceiling: Painted concrete ceiling
Demo Picture		

Table 3 Technical specifications of light used for the simulations

Lamp Parameters	Philips - LL612XLED 31S/830 NB HE	Philips - TCW060 1xTL-D18W HF
Lamp Flux (lm)	2650	1350
Total Flux (lm)	2638	918
Luminous Efficacy (lm/W)	146.6	48.3
Correlated Color Temp. [CCT] (K)	3000	3000
Color Rendering Index [CRI]	80	100
Light Output Ratio [LOR] (%)	100	68
Total Power (W)	18	19
Lamp Type	Baten type	Baten type

4. Simulation Result and Analysis

In laboratories, there should be at least 300 lux of illumination, according to MS1525. Figure 2 shows the measured levels of illumination at several positions in the laboratories under various natural lighting conditions. The Signal Processing Lab has 112 luminaries, whereas the Electronics 1 Lab has 48 luminaries. The other two natural illumination conditions are more than enough for the laboratories, with the exception of an overcast sky and at night.

4.1. Signal Processing Lab

Under the overcast sky lighting situation for Signal Processing Lab, the present illumination setup is wasting the light energy in comparison to MS1525 guideline [see Figure 2].

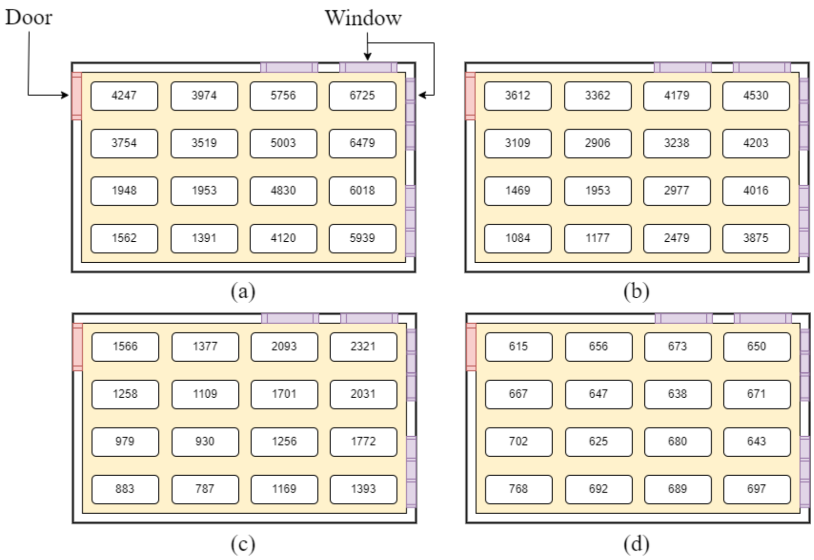
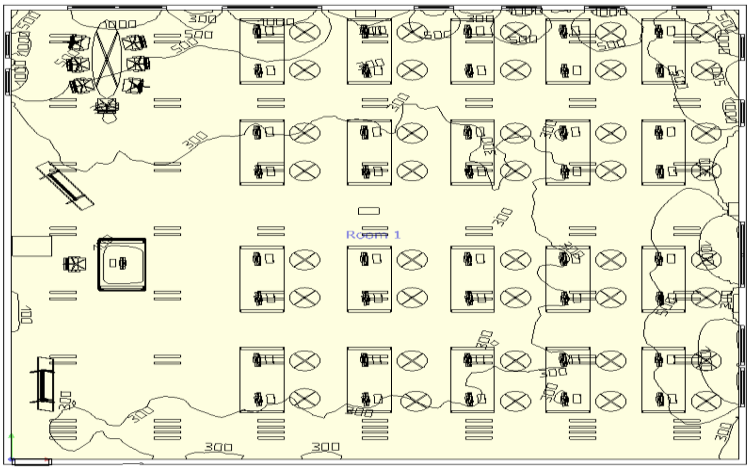
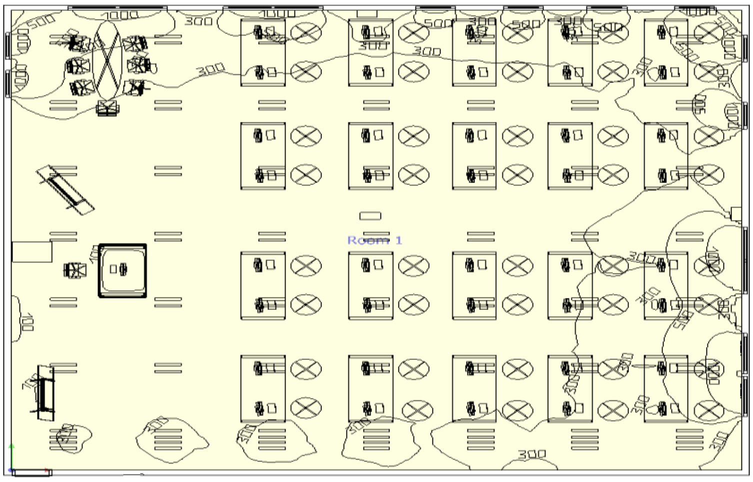


Fig. 2 Measured illuminance level in the Signal Processing Lab at different positions for: (a) clear sky, (b) average sky, (c) overcast sky, and (d) at night [Philips-TCW060 1xTL-D18W HF]

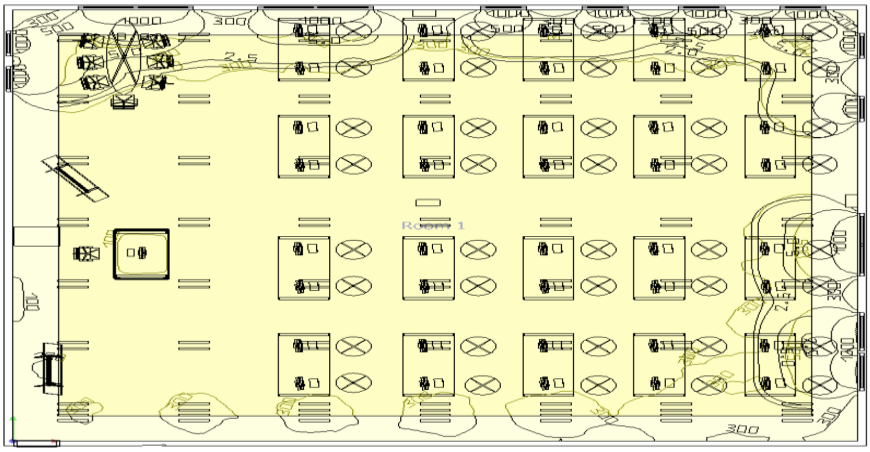
As can be seen from Figures 2 and 3, the illuminance level differs from the measured values even though the simulation results for clear sky and average sky illumination conditions indicate that there is enough light in the Signal Processing Lab. As shown by Eq. (1), the maintenance factor (MF), which is a composite of several different characteristics, may be one of the causes.



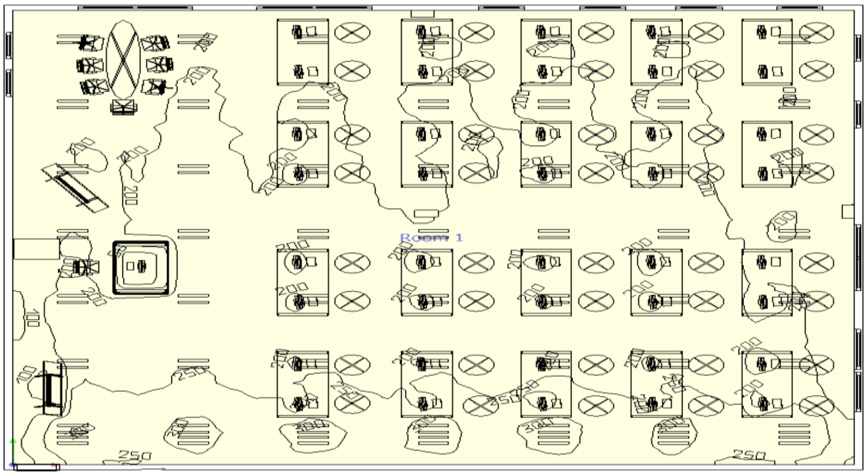
(a)



(b)



(c)



(d)

Fig. 3 Simulated illuminance level for the Signal Processing Lab at different positions for: (a) clear sky, (b) average sky, (c) overcast sky, and (d) at night [considering same Philips-TCW060 1xTL-D18W HF light for simulation]

The results from the simulation are somewhat consistent with the measured values for the overcast sky condition, more so on the window side. The position of the laboratory (Signal Processing Lab) might be the reason. Specifically, the side near the window is fully open and gets enough natural light, while the other side does not. This side of the room is where a corridor and additional rooms are situated. Therefore, although the simulation result shows the theoretical value, the measured light (using a luxmeter) shows the actual condition.

The result indicates sufficient light (≥300 lux) in terms of night lighting simulation; however, it differs greatly in real measurement while using same model light for both measured and simulated condition. The main cause of this variance is that existing tube light position and low maintenance, besides light get dimmer after a long usage, while in our simulation, we identified the proper light position for the Philips-TCW060 1xTL-D18W HF light, which is appropriate for excellent illumination and has a simple, attractive design.

4.2. Electronics 1 Lab

The Electronics 1 laboratory, as shown in Figures 4 and 5 depicts measured and simulated value respectively.

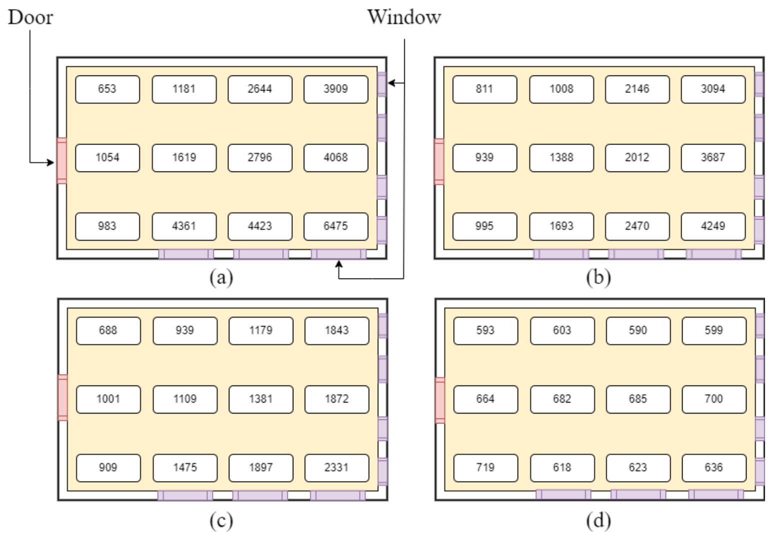
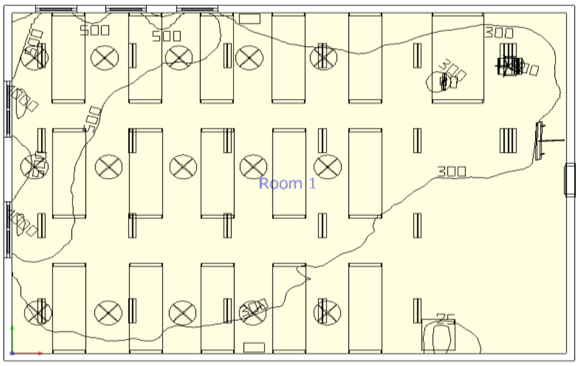
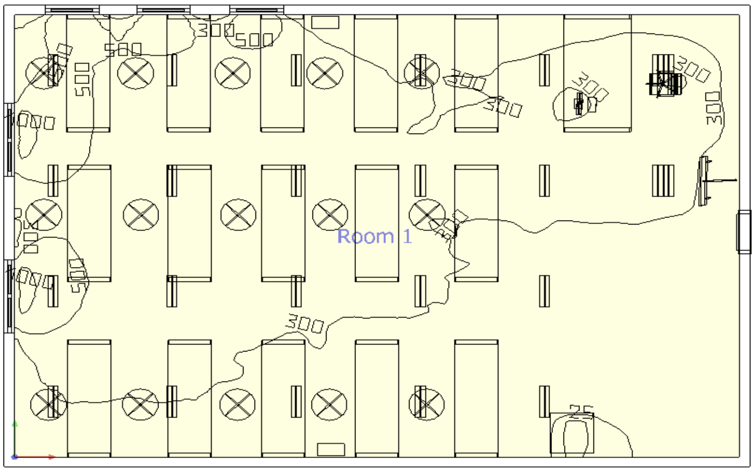


Fig. 4 Measured illuminance level in the Electronics 1 Lab at different positions for: (a) clear sky, (b) average sky, (c) overcast sky, and (d) at night [Philips-TCW060 1xTL-D18W HF]

Electronics 1 Lab is also surpassing the MS1525 guideline. In addition, the measured levels of illumination in both rooms suggest that the lights are not equivalent in effectiveness as standard tube lights with ballasts. Figure 5 illustrates the simulated lighting illumination level for Electronics 1 Lab utilizing *Philips-TCW060 1xTL-D18W HF* light in simulation.


500
500
300
300
Room 1

(a)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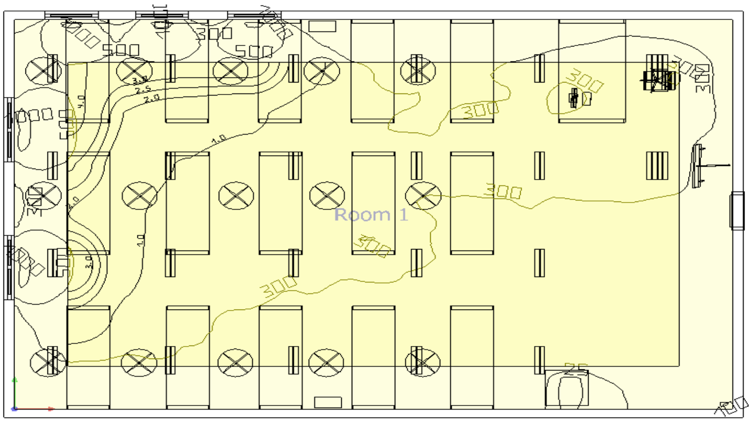
Room 1
300

(b)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300
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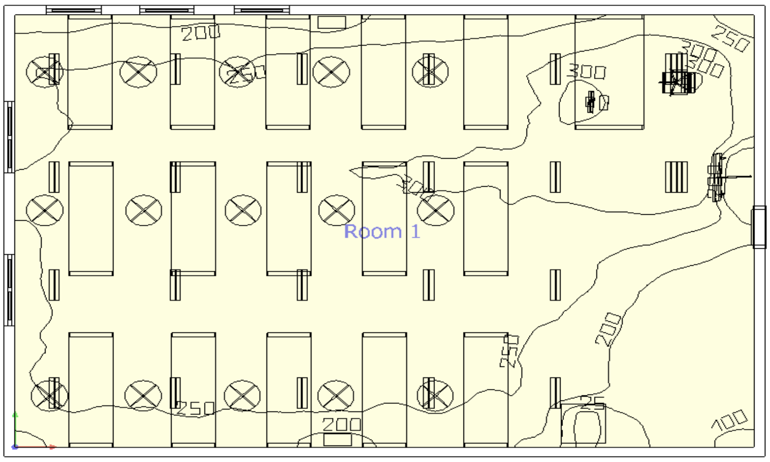
300
300
Room 1
300

(c)

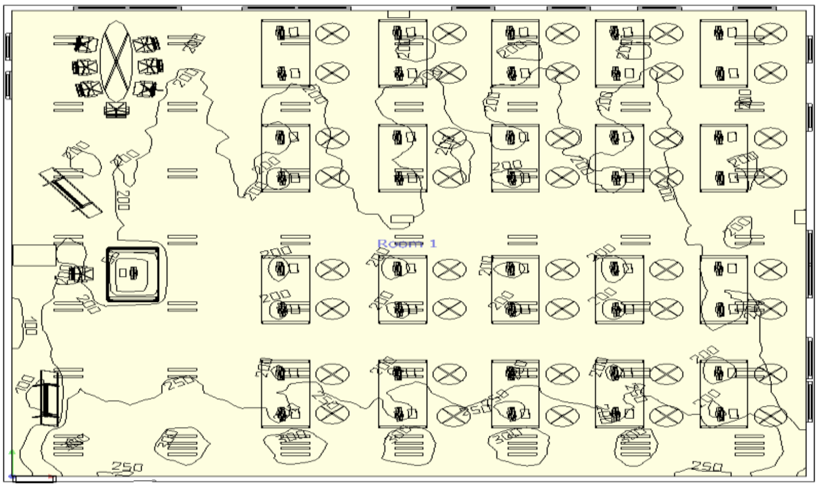


(d)

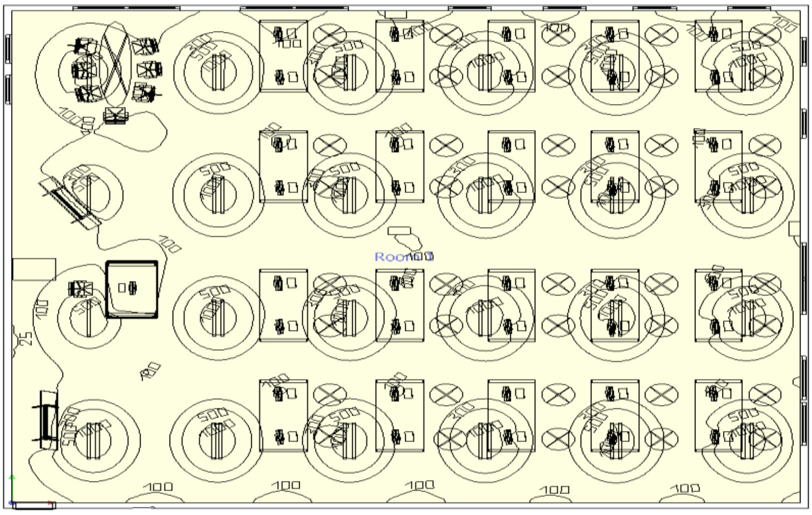
Fig. 5 Simulated illuminance level for the Electronics 1 Lab room at different positions for: (a) clear sky, (b) average sky, (c) overcast sky, and (d) at night [considering same Philips-TCW060 1xTL-D18W HF light for simulation]

4.3. Proposed LED Lighting System for Both Labs

The measured levels of lighting system for both labs are not appropriate, energy wasting and doesn’t follow the MS1525 guidelines. In order to mitigate these issues, LED tube lights are the solution [24], and it could be used in the design of a more effective lighting system.



(a)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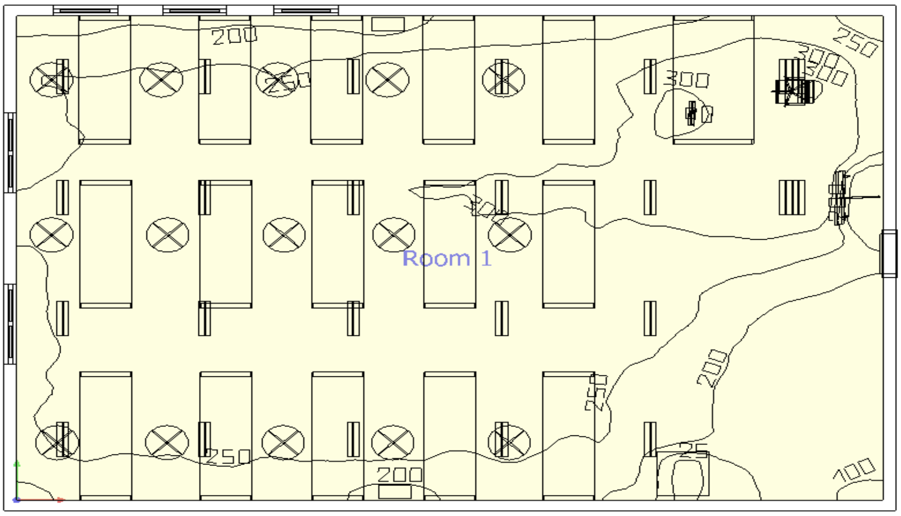
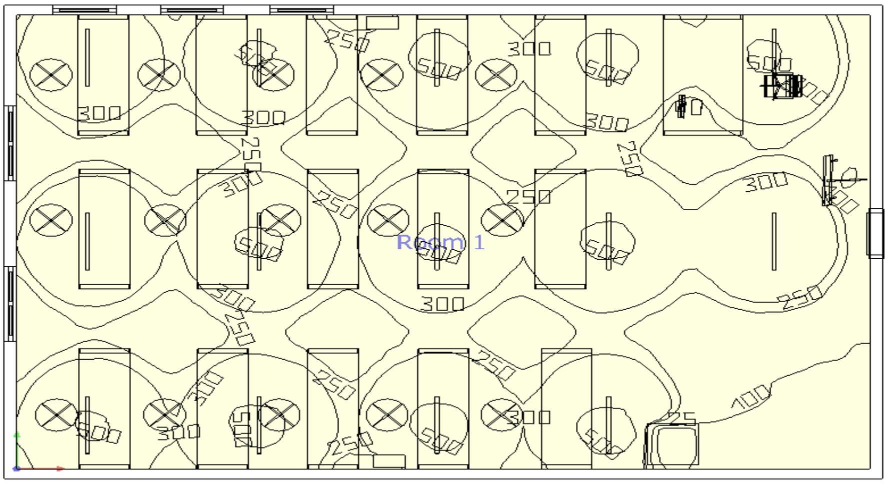
(b)


200
250
250
300
200
Room 1
200
250
250
200
100

(c)



(d)

Fig. 6 Comparative simulation illuminance level for the Signal Processing Lab room with: (a) 112 typical tube lights, (b) 45 LED tube lights; and Electronics 1 Lab room with: (c) 48 typical tube lights, and (d) 14 LED tube lights. Here, typical tube light: Philips-TCW060 1xTL-D18W HF and LED tube light: Philips-LL612X LED31S/830 NB HE

It appears that for the Signal Processing Lab, the illuminance level that could be achieved with 45 LED tube lights is superior to that with 112 normal tube lights [see Figure 6(a) and (b)] and 14 LED tube lights rather than 48 normal tube lights were utilized; as a result, the Electronics 1 Lab could achieve a higher illumination level with the former than with the latter [see Figure 6(c) and (d)].

4.4. Cost and Environmental Benefit Analysis

Using LED could be effective in various ways. Tables 4 and 5 show that LED lights are more expensive per unit than normal tube lights. Nonetheless, this LED lighting system may save a significant amount of energy and money when compared to normal tube lighting for the room. For the Signal Processing Lab and the Electronics 1 Lab, the average level of illumination was increased by 74 and 80 lux, respectively.

Table 4 Cost-benefit analysis for Signal Processing Lab

Sl. No	Type	LED tube light	Typical tube light
1	Price (RM)	43 RM (average unit price-only for light) 43 x 45 = 1935	24 RM (average unit price-only for light) 24 x 112 = 2688
2	Average illuminance level (lux)	444	370
3	Energy consumption (kWh/Year)	647 - 1077.30	1740.14 - 2830.24
4	Energy cost (RM/kWh)	0.365	0.365
5	Total cost (RM/Year)	647 x 0.365 = 236.16 (Min) 1077.30 x 0.365 = 393.22 (Max)	1740.14 x 0.365 = 635.15 (Min) 2830.24 x 0.365 = 1033.04 (Max)
6	Benefits: energy and cost savings	1093.14 - 1752.94 kWh/Year 398.9961 - 639.8231 RM/Year	
7	Benefits: quality of light	Increased illuminance level: (444 – 370) = 74 lux	

Table 5 Cost-benefit analysis for Electronics 1 Lab

Sl. No	Type	LED tube light	Typical tube light
1	Price (RM)	43 RM (average unit price-only for light) 43 x 14 = 602	24 RM (average unit price-only for light) 24 x 48 = 1152
2	Average illuminance level (lux)	402	322
3	Energy consumption (kWh/year)	377.61 - 567	1452.27 - 2052
4	Energy cost (RM/kWh)	0.365 (Unit price for commercial consumers)	0.365 (Unit price for commercial consumers)
5	Total cost (RM/Year)	377.61 x 0.365 = 137.83 (Min) 567 x 0 .365 = 206.96 (Max)	1452.27 x 0.365 = 530.08 (Min) 2052 x 0.365 = 748.98 (Max)
6	Benefits: energy and cost savings	1074.66 - 1485 kWh/Year 392.2509 – 542.025 RM/Year	
7	Benefits: quality of light	Increased illuminance level: (402 – 322) = 80 lux	

Regarding the decrease of greenhouse gas emissions resulting from this energy saving, it was calculated that by avoiding the generation of power from fossil fuels, 41,012.43 to 65,766.81 kgCO2-eq for the Signal Processing Lab and 40,319.09 to 55,714.23 kgCO2-eq for the Electronics 1 Lab could be saved annually. According to [29, 30], the average annual carbon intensity of developing countries of 670 gCO2-eq/kWh was taken into account for this assessment.

5. DISCUSSION

Nearly all Malaysian government institutions use normal fluorescent tube lights in their offices and classrooms, according to personal conversations with both academic and non-academic staff members of several different universities. Clearly, these educational institutions can definitely save energy by upgrading to LED lighting. Using LEDs has economic and environmental advantages in addition to energy savings. Students at universities found that LED lighting is more advanced technologically, pleasing to the eye, energy-efficient, exciting, and comfortable than fluorescent lighting [31]. Normal fluorescent tubes include phosphor and mercury, which can be hazardous to the environment and human health once their life expires. Fluorescence tube lights that have reached the end of their useful life pose a significant threat to the environment because they have the potential to contaminate land and water with obsolete light production components such as mercury. This is because the least developed countries do not have adequate waste disposal systems. In contrast, these substances are absent from LED tubes. In addition to raising the lamp cost, ballast is necessary for fluorescent tubes to function and is also the cause of the familiar buzzing sound. Fluorescent tube lights sometimes have dulling and flickering issues, however LED tube lights do not have these issues. LED lights are around three times more expensive than standard fluorescent tube lights, despite the fact that they have several benefits over the latter.

Despite the fact that LED lighting systems provide numerous benefits in comparison to fluorescent tube lights for educational institutions, there are a number of challenges that must be overcome before this more efficient design can be used. At the outset, there is a deficiency in knowledge. In point of fact, the initial cost of an LED lighting system is higher than that of a fluorescent tube light, and the competent authority is frequently prevented from taking into consideration the cost savings that an LED lighting system offers over its lifespan due to a lack of content. Second, there is lack of knowledge about the surroundings. In poor and least developed nations, lighting is one of the main uses of electricity, and most users are unaware that power is generated. The detrimental effects of energy production that is driven by fossil fuels, as well as the detrimental repercussions that it has on the environment and public health, receive less attention. Third, there is difficulty with change. The government and authorities frequently emphasize the need of obtaining power at a low cost from reputable providers; nevertheless, these suppliers sometimes cannot provide energy-efficient items because of their relatively high initial cost. Furthermore, there is a lack of knowledge among the staff members involved in this procurement process on the benefits of energy-efficient choices. Lastly, notable is the absence of expertise in the design of lighting systems. Architects and civil engineers are often given priority in the planning, building, and interior design phases of any project. The local technician, who has little understanding of lighting efficacy aspects, typically designs lighting systems.

Revision or development of policies is necessary to get beyond these obstacles. Several suggestions for these modifications consist of:

- The development of procurement staff knowledge and abilities via various training efforts and programs is crucial to their ability to make well-informed decisions on the efficiency and financial viability of purchasing new lighting systems. These awareness efforts must include subjects related to sustainable development and the environment.

- To obtain precise and all-encompassing information on energy-efficient lighting and its related benefits, consulting experts with experience in this field would be an extremely effective strategy. In this case, hiring an expert to do an energy audit might also be beneficial.
- Regarding industrial lighting system design, it is essential to retain the services of an experienced lighting system specialist or lighting engineer during the facility's planning and building phases. Several factors must be taken into consideration while designing a lighting system. [32].
- Demand side management programs should be implemented by all educational institutes to maximize energy resource usage, especially with regard to lighting systems.
- Laws governing the adoption and use of more energy-efficient lighting system design and usage in the educational institutes and all other industries must be established by the national government. Every industry should first conduct a pilot project to create a more energy-efficient lighting system and take the project's results into consideration.
- Make a conscious choice to choose solar photovoltaics (PV) for your primary energy source. Due to the fact that solar photovoltaic (PV) technology may function as a very effective primary light source in an emergency, as proved by empirical evidence [33].

6. Conclusion

In this study, the goal of the simulation exercise and genuine lighting level measurement was to comprehend how thoughtful lighting system design may help save electrical energy and provide visual comfort within an educational institution in Malaysia. An efficient lighting system based on LEDs was offered as a solution to the drawbacks of the current system. The results demonstrate that this kind of lighting system might save an astounding amount of money and energy annually. The suggested LED-based lighting system offers long-term financial and environmental advantages, despite its higher starting costs when compared to the typical fluorescent tube system. Compared to a typical fluorescent tube light, an LED tube light has nearly double the lifespan. Moreover, dangerous elements like mercury are absent from the later but present in the former.

When designing an energy effective illumination system, just increasing the overall number of lights is not necessarily the best choice. This is because the type of light is equally as important as the quantity. Another possible way to lower energy consumption in buildings is to maximize the use of natural light in conjunction with artificial lighting; this is something that has to be considered when designing any lighting system for educational institutions.

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