UNIVERSITI TEKNOLOGI MARA

PEKELILING TIMBALAN NAIB CANSELOR (PEMBANGUNAN)

Bilangan 5 Tahun 2021

PELAKSANAAN KOD AMALAN MENAIK TARAF LAMPU DALAMAN KEPADA LAMPU LED DI UNIVERSITI TEKNOLOGI MARA (UiTM)

TUJUAN

1. Pekeliling ini dikeluarkan bertujuan untuk memaklumkan kepada semua Ketua Pusat Tanggungjawab (PTJ) mengenai pelaksanaan kod amalan untuk menaik taraf lampu dalaman kepada lampu LED di seluruh sistem UiTM.

LATAR BELAKANG

2. UiTM telah menggunakan sistem lampu yang terdiri daripada lampu *flourencent* jenis T8 dan T5 untuk pemasangan di dalam bangunan seperti di ruang pejabat, bilik kuliah, makmal dan koridor. Manakala lampu limpah digunakan di makmal berat, dewan dan ruang-ruang lain di dalam bangunan.

3. Berdasarkan kepada analisa keberkesanan yang telah dijalankan, merangkumi analisa perbandingan kos peyelenggaraan, jangka hayat, keupayaan pencahayaan dan kecekapan tenaga, adalah didapati penggunaan lampu jenis LED adalah lebih memberikan faedah jangkamasa panjang kepada UiTM berbanding dengan sistem lampu sedia ada.

4. Pelaksanaan ini adalah selaras dengan langkah-langkah untuk:

   i. membudayakan amalan penjimatan penggunaan tenaga di dalam kampus.
   ii. menyediakan kualiti pencahayaan dengan susut nilai yang rendah setiap tahun.
   iii. mengurangkan kos penyelenggaraan sistem lampu di dalam bangunan. Antara faktor pengurangan ialah lampu LED dibekalkan dengan jaminan 5 tahun oleh pengeluar dan jangka hayat penggunaan lampu LED adalah lebih daripada 10 tahun (atau 25,000 jam).

5. Oleh yang demikian, setelah meneliti dari semua aspek, Bahagian Pengurusan Fasiliti (BPF) seluruh sistem UiTM akan menguatkuasakan pelaksanaan penukaran lampu *flourecent* sediada yang telah rosak kepada lampu LED mengunakan kontrak perkhidmatan pembaikan dan penggunaan lampu LED untuk kerja-kerja ubahsuai ruang

menggunakan kontrak kerja. Untuk makluman, kontrak perkhidmatan pembaikan dan kontrak kerja ini adalah di bawah pengurusan BPF.

PELAKSANAAN

6. Pelaksanaan pekeliling ini akan dijalankan oleh Bahagian Pengurusan Fasiliti di seluruh sistem UiTM, melibatkan kerja-kerja penukaran lampu rosak, menaik taraf ruang dan projek pembangunan baru.

CAPAIAN DOKUMEN

7. Pekeliling ini adalah merujuk kepada SIRIM Standard SIRIM33:2019 *Code of practice for upgrading of interior lighting with LED lamps and luminaires.* Dokumen tersebut boleh dilihat dan dimuat turun menerusi pautan *https://ppii.uitm.edu.my/.*

PEMAKAIAN

8. Pekeliling ini adalah terpakai kepada semua warga Universiti Teknologi MARA

TARIKH DIKELUARKAN

9. Pekeliling ini dikeluarkan pada 22 Jun 2021.

TARIKH KUAT KUASA

10. Pekeliling berkuatkuasa pada 1 Jun 2021.

PROFESOR DATO' Ts. DR. MOHD FOZI ALI
Timbalan Naib Canselor (Pembangunan)

Dikelilingkan kepada:
Timbalan-timbalan Naib Canselor
Pendaftar
Bendahari
Rektor-rektor UiTM Cawangan
Dekan-dekan Fakulti/ Pengarah-pengarah Pusat Akademik
Ketua-ketua Jabatan/Bahagian/Pusat/Unit

Bil. Fail : 100-PPII (PTA. 6/7/3)
No Siri : Pekeliling Timbalan Naib Canselor (Pembangunan)

SIRIM STANDARD

SIRIM 33:2019

ICS: 91.160.10

Code of practice for upgrading of interior lighting with LED lamps and luminaires

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Foreword

This SIRIM Standard was developed by the Project Committee on Upgrading of Interior Lighting with LED Lamps and Luminaires established by SIRIM Berhad.

This standard was developed with the following objectives:

a) to promote energy conservation practices;

b) to reduce operating costs for buildings and similar facilities;

c) to enhance the installation and operation safety; and

d) to enhance lighting quality and provide visual comfort to users.

This standard does not override or increase requirements specific to any laws and regulations that may be applicable. However, to the greatest extent practicable, this standard should be considered by organisations involved in the lighting industries business, where both economic efficiency and improved environmental performance can be achieved.

This standard does not include the safety requirements of the LED lamps and luminaires, as these requirements are covered by the relevant Malaysian Standards.

This standard will be reviewed periodically, and if necessary, revised, to ensure that it reflects current needs and conditions. Users and other interested parties may submit comments on the contents of this standard for consideration in future versions.

Compliance with this standard does not by itself grant immunity from legal obligations.

Code of practice for upgrading of interior lighting with LED lamps and luminaires

0. Introduction

Electrical energy consumption is expected to increase in Malaysia with lighting being the second largest contributor to overall electrical power consumption. Around 15 % of all electricity in Malaysia is used for lighting in buildings. Incandescent lamps and compact fluorescent lamps (CFL) are still the dominant types of lamps used in Malaysia, both of which consume a relatively high amount of energy. In comparison, with the recent advent of highly efficient Light Emitting Diode (LED) technology and related lighting solutions, residential, commercial and public building owners worldwide are giving more serious consideration to the upgrading of their lighting systems.

There are three approaches for upgrading lighting systems that can be completed at varying levels of complexity and cost, as follows:

a) Retrofit - component replacement: involves simple component replacement, such as relamping or reballasting existing luminaires. This approach offers the lowest cost but typically leads to high cost in maintenance and energy inefficiency.

b) Retrofit - luminaires replacement: involves replacing whole luminaires. This is the normal approach where the effectiveness is adequate in engineering works. However, the desired long term energy efficiency may not be achievable.

c) Redesign: involves total redesign and installation using new products and current best practices according to the needs and engineering requirements.

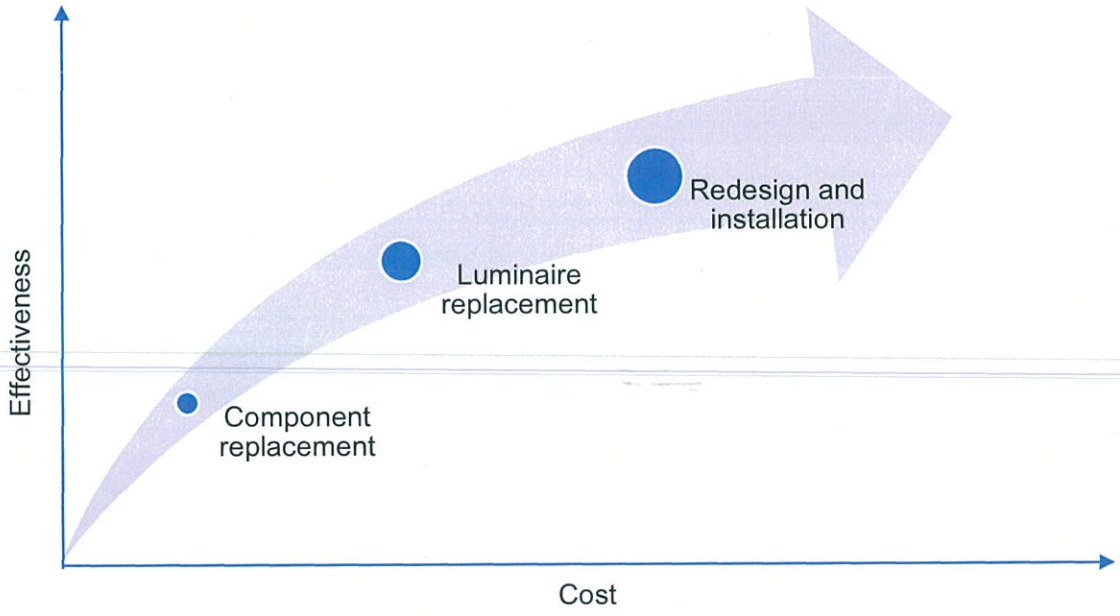

Figure 1. The cost and effect analysis of the system variation

Good lighting will create a visual environment that enables people to see, move about safely and perform visual tasks efficiently, accurately and safely without causing undue visual fatigue and discomfort. It requires equal attention to the quantity and quality of the lighting.

With affordable, high quality LED lighting, upgrading is an effective method to reduce users' operating expenses while increasing their light quality. But not all LED upgrades are created equal and the simplest of projects can quickly become a challenge with the wrong solution in hand. Lack of standards for best practices in implementing LED lighting upgrades could lead to the following issues:

a) site-audit is not conducted comprehensively by a trained or certified lighting auditor resulting in the project not delivering light quality according to recommended illumination standards;

b) implementing upgrading projects without comprehensive economic analysis, which may mislead by the "apparent" cost savings of the proposed upgrade;

c) improper installation and use of uncertified lighting products that may pose a fire or shock hazard; and

d) reliability and performance of most new and evolving LED lighting technologies, such as dimmable electronic ballasts and microprocessor controls have not been successfully tested and used in a commercial application for at least one year.

Although it is recognised that the use of LED lamps and luminaires is sustainable in the long-term and will definitely displace the conventional lighting products in years to come, the adoption of LED lighting in Malaysia is not as fast or widespread as in developed countries. This could possibly be attributed to lack of awareness among Malaysians about energy-efficient products and the resistance to accepting the new technology due to the high capital cost. Apart from this, many of the LED products currently in the market are of poor quality and are not as reliable as publicly claimed by the sellers or retailers.

This standard gives general guidelines to assist individuals and professionals in understanding and implementing the whole chain of LED lighting upgrading processes for better economic benefits and environmental sustainability.

1. Scope

This standard provides guidance for a systematic approach in planning, designing, installing and maintaining of Light Emitting Diode (LED) lighting upgrading for general illumination in residential, public and commercial buildings.

This standard is intended to be used by project designers, contractors, energy service professionals, regulatory bodies, building owners and traders.

This standard may also provide useful guidance for the installation of LED lighting equipment in a new building.

2. Normative references

The following normative references are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies.

MS 1936, *Electrical installations of buildings - Guide to MS IEC 60364*

MS 1979, *Electrical installations of buildings - Code of practice*

MS 2598, *Minimum energy performance standards (MEPS) for lamps*

MS 1525, *Energy efficiency and use of renewable energy for non-residential buildings - Code of practice*

MS IEC 60038, *IEC Standard voltages*

MS IEC 60364, *Electrical installations of buildings*

MS IEC 62717, *LED modules for general lighting - Performance requirements*

MS ISO 8995, *Lighting of indoor work places*

CIE 58, *Lighting for sports halls*

CIE 63, The *Spectroradiometric measurement of light sources*

CIE 117, *Discomfort glare in interior lighting*

IEC 60050-845, *International electrotechnical vocabulary - Part 845: Lighting*

IEC 62471, *Photobiological safety of lamps and lamp systems*

IEC TR 62778, *Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires*

IEEE 1789, *IEEE recommended practices for modulating current in high-brightness LEDs for mitigating health risks to viewers*

LM-79, *Approved method for the electrical and photometric measurements of solid-state lighting products*

Electricity Supply Act 1990 (Act 447)

Electricity Regulations 1994

3. Terms and definitions

For the purposes of this standard, the terms and definitions given in IEC 60050-845 and the following apply.

3.1 candela (cd)

SI unit of luminous intensity. The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

1 cd = 1 lm • sr $^{-1}$

3.2 Colour Rendering Index (CRI)

Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

3.3 Correlated Colour Temperature (CCT)

Applies to sources with a continuous spectrum (such as incandescent lamps and natural light). However, for light sources with non-continuous spectral distribution (such as fluorescent lamps and discharge lamps where the spectrum consists of peaks of energy), CCT is used mainly on an empirical sense (i.e. in a very 'near approximate' sense) to describe the degree of 'whiteness' of the said light source.

unit: Kelvin (K)

3.4 Illuminance (at a point of a surface, E, E_v)

Quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element.

Equivalent definition: Integral, taken over the hemisphere visible from the given point of the expression $L_v \cdot \cos\Theta \cdot d\Omega$, where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and Θ is the angle between any of these beams and the normal to the surface at the given point.

$$E_V = d\Phi_v/dA = \int_{2\Pi sr} (L_V \times \cos\Theta \times d\Omega)$$

unit: lx = lm • m^{-2}

3.5 lamp

Source made in order to produce an optical radiation, usually visible.

3.6 Light Emitting Diode (LED)

Solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current.

3.7 LED lamp efficacy

Quotient of the luminous flux emitted by the power consumed by the LED lamp.

NOTE. Efficacy is expressed in lm/W.

3.8 LED luminaire

Luminaire designed to incorporate one or more LED light source(s).

3.9 LED luminaire luminous efficacy

Quotient of the luminous flux emitted by the power consumed by the LED luminaire.

3.10 lighting

Application of light to a scene, objects or their surroundings so that they may be seen.

3.11 lumen

SI unit of luminous flux: Luminous flux emitted in unit solid angle (steradian) by a uniform point source having a luminous intensity of 1 candela.

3.12 lumen maintenance factor

Ratio, expressed as a percentage *x*, of the luminous flux emitted by the light source at a given time in its life to its initial luminous flux emitted.

unit: %

NOTE. The lumen maintenance factor of a LED light source includes optical parts degradation, the effect of decrease of the luminous flux output of the LED package and failure(s) of individual LED packages if the LED light source contains more than one LED package.

3.13 luminaire

Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

3.14 luminance (in a given direction, at a given point of a real or imaginary surface, L_V, L)

Quantity defined by the formula

$$L_V = d\Phi_V/(dA \times \cos\Theta \times d\Omega)$$

where $d\Phi_V$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point and Θ is the angle between the normal to that section and the direction of the beam.

unit: cd • m^{-2} = lm • m^{-2} • sr^{-1}

3.15 lux

SI unit of illuminance: Illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface.

1 lx = 1 lm • m^{-2}

3.16 maintained value

Photometric and electrical characteristic at an operational time under LM-79 standard test conditions, including stabilisation time.

4. Process flow

The LED lighting upgrading process shall be conducted according to Figure 2.

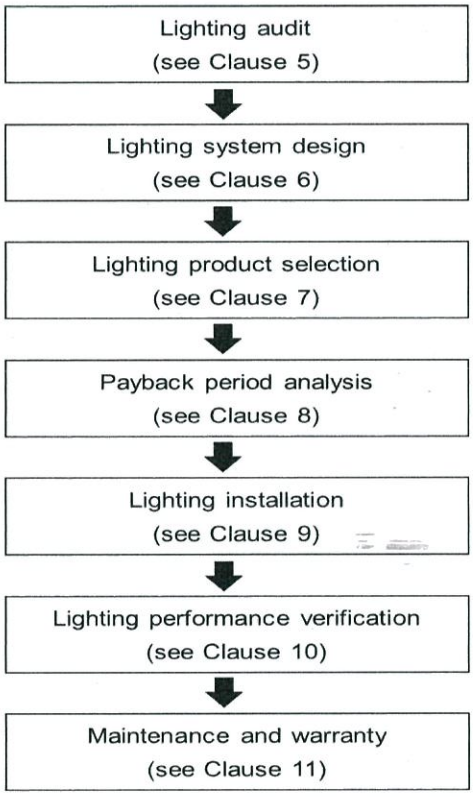

Figure 2. LED lighting upgrading process

5. Lighting audit

5.1 Lighting audit shall consist of:

a) inventory evaluation on the existing lighting fixtures in each functional area of an interior space;

b) measuring light delivered to all significant areas and surfaces; and

c) comparing those measurements against MS ISO 8995.

5.2 A lighting audit shall be conducted by a trained lighting auditor with at least three years' experience in lighting installation.

5.3 The auditor shall use the following steps to conduct a lighting audit.

5.3.1 Equipped with basic lighting-audit tools:

a) detailed floor plan for interior lighting to be audited;

b) tape measure;

c) electrical power-meter capable of measuring voltage, current, power and power factor;

d) spectrophotometer capable of measuring illuminance, CRI and CCT;

e) light flicker meter; and

f) audit worksheet (see Figure A.1 for example).

5.3.2 Organising and recording the audit as follows:

a) organise the audit using the floor plan by recording the precise section of each lighting fixture on the plan;

b) create an inventory worksheet entry for each lighting fixture, noting the plan room or space in which it is located, as well as the type of fixture and the number of its lamps and ballasts, together with the type, wattage and model number of each lamp (see Figure A.2 for example); and

c) record the normal hours of operation per year of each fixture.

5.3.3 Measuring performance shall follow the steps below.

a) Using a tape measure, determine the distance of each lighting fixture from the areas and surfaces it was installed to illuminate, and record those distances in the worksheet section for each fixture.

b) Using the spectrophotometer, measure the actual illumination level, CRI and CCT at each of the various areas and surfaces under the audit worksheet.

c) Using the power meter, measure the electrical power consumption of each sector according to MS ISO 8995.

d) Record these performance measurements in the audit worksheet section dedicated to the light fixture.

5.3.4 Compliance analysis

Evaluate the performance of the system according to MS ISO 8995.

5.3.5 Recommending solutions

The auditor shall propose an upgrading plan to provide lighting levels to all interior areas under evaluation according to recommended illuminance in MS ISO 8995.

6. Lighting system design

6.1 General

Interior lighting system can be divided into two categories - task and building lighting area(s). From the findings of the lighting audit, successful upgrading into LED lighting system for both areas shall be based on optimised illumination for visual task, its surrounding and background (see Figure 4). Lighting simulation software shall be utilised to provide fast and precise analysis in optimising of the overall upgrading system.

6.2 Visual task

6.2.1 Design consideration

6.2.1.1 Illuminance

The actual level shall depend on the visual difficulty of the task, the age of the person and the quality of the person's sight and the degree of accuracy of performance necessary. Table B.1 lists the number of typical tasks together with their recommended illuminance for people with normal vision.

6.2.1.2 Uniformity

The distribution of light across the task area shall be as uniform as possible.

The uniformity of the illuminance is the ratio of the minimum to average value. The illuminance shall change gradually.

See Table B.1 for the uniformity (U_o).

6.2.1.3 Glare

All glare avoidance should be in accordance with Table B.1.

All bright sources shall be excluded from the normal and reflected field of view to minimise glare which is likely to cause at least distraction, possibly visual discomfort or, in extreme cases, visual disability.

Reflected glare from light that reflects off the work piece as shown in Figure 3 shall also be avoided.

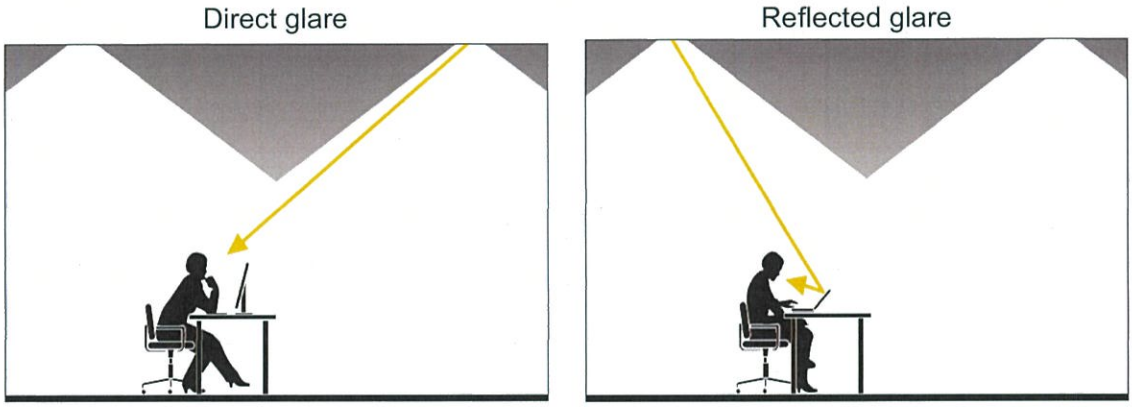

Figure 3. Example of direct and reflected glare from work piece
[Source: The Lighting Handbook]

6.2.1.4 Colour rendering

The colour performance of a light source shall be considered with respect to the task and to the appearance of the room.

This effect is described by the term 'colour rendering', which for lamps can be described by a general colour rendering index (R_a).

See Table B.1 for the minimum colour rendering index (R_a).

6.2.1.5 Colour appearance

The 'colour appearance' of a lamp shall refer to the apparent colour (lamp chromaticity) of the light it emits which is described by its CCT.

The choice shall depend on illuminance, colours of the room and furniture, surrounding climate and the application.

6.2.1.6 Maintenance factor

The recommended lighting levels for each task shall be provided as maintained illuminance which depends on the maintenance characteristic of the lamp, the luminaire, the environment and maintenance programme.

The lighting scheme should be designed with a maintenance factor calculated for the selected lighting equipment (such as luminaire, lamp and control gear), environment and specified maintenance schedule.

Maintenance factor is a factor that allows for the fact that, as lighting systems age, the amount of light they deliver decreases. The use of maintenance factor ensures that the system is slightly over-specified when new but is still delivering the correct illuminance when the system is maintained.

6.3 Lighting for surrounding and background

6.3.1 The lighting of an interior should take account of the space, and its surface materials and colours to create the right atmosphere and degree of visual stimulation for the particular application (see Figure 4).

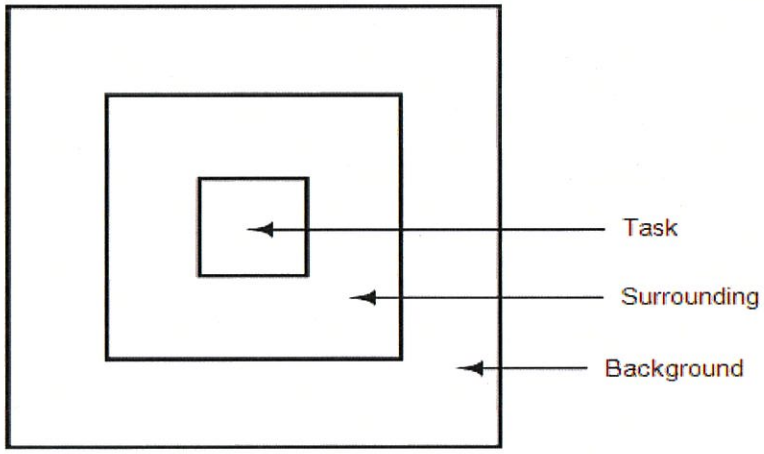

Figure 4. Definition of task and building lighting areas
[Source: ILO Encyclopaedia of Occupational Health and Safety]

6.3.2 For example, amenity lighting should be considered as 'building lighting' as opposed to 'task lighting', where it is necessary to use a combination of direct illuminance and a high reflectance surface.

6.3.3 Attention also should be given to adaptation in moving from zone to zone within a building. For example, the transition from bright areas to less bright areas needs to be considered.

6.4 Lighting simulation

6.4.1 Lighting simulation software (e.g. DIALux, Relux, etc.) shall be used for planning, calculation and visualisation of indoor lighting.

6.4.2 The 3-D visualization should provide more accurate/optimal design, micro effect on space planning and isolux diagram plot and glare calculation.

6.4.3 The simulation should be conducted by personnel who have undergone at least basic training on the use of the software.

7. Lighting product selection

7.1 Lighting for architectural integration

The selection of types of luminaire and their visible appearance should fit in with the overall style of the building. Factors that need to be considered are:

a) lighting performance;

b) layout of the work areas; and

c) future planning for change or renovation.

7.2 Lighting for energy efficiency

The lighting installation should meet the lighting requirements of a particular interior, task or activity without waste of energy. However, it is important not to compromise the visual aspects of a lighting installation simply to reduce energy consumption. This requires the consideration of appropriate lighting systems, equipment, controls and the use of available daylight.

7.2.1 Daylight

If the selected upgrading process is by redesigning new interior lighting system, then the existing daylight performance potential shall be assessed for its improvement.

Once this has been determined, recommendations stated in MS 1525 should be considered on how electric lighting can be used to complement the daylighting.

7.2.2 Lighting control

Automatic control mechanisms, such as those listed below, should be used to provide suitable switching patterns for energy efficient lighting:

a) daylighting sensor for the ability to vary artificial light output relative to the daylight for perimeter lighting;

b) time switches to switch lights on/off/dim at convenient times during the day when it is expected that either there will be sufficient daylight in the interior, or that it will be unoccupied; and

c) occupancy sensors to switch lights on or off automatically when people enter or leave a close space.

7.2.3 Light flicker

The LED lighting system operating on a normal 50 Hz mains electricity supply shall be designed to avoid light flicker effect according to IEEE 1789. Light flicker causes distraction and may give rise to physiological effects such as headaches.

The Recommended Practice 1 for Low-Risk Level leads to Modulation (%) satisfying Mod % < 0.08 × 100 Hz = 8 % (rounded to the nearest percent).

The Recommended Practice 2 for No Observable Effect Level (NOEL) leads to Modulation (%) satisfying Mod % < 0.0333 × 100 Hz = 3 % (rounded to the nearest percent).

7.3 Safety and regulatory compliance

7.3.1 Upgrading lighting system components is not as simple as changing a traditional light bulb. Fluorescent lamps and lighting systems are not generally compatible with LED-based lamps and luminaires. Therefore, an upgraded lighting system shall be designed and implemented so that it continues to function as intended, that lighting application performance requirements are met, and that safety is not compromised.

7.3.2 The following aspects shall be considered.

a) The LED lighting products shall comply with the requirements of the Electricity Regulations 1994 as elaborated in Suruhanjaya Tenaga's Guideline for Approval of Electrical Equipment.

b) The energy performance of self-ballasted LED lamps for general lighting services shall comply with the Minimum Energy Performance Standards (MEPS) specified in MS 2598.

c) Wireless smart lighting products shall comply with the requirements of the Malaysian Communications and Multimedia Commission Act (1998) as elaborated in the relevant MCMC Technical Specification.

d) Photobiological safety for the product should be under exempt group as defined in IEC 62471 and IEC TR 62778.

e) Since most lighting technologies subject to retrofitting should be designed to support the lighting controls in place at the time of their installation, it is important to verify that prospective lighting products are compatible with the currently installed or planned daytime controls, dimmers and other devices.

8. Payback period analysis

8.1 Consideration of costs is a major part of the LED lighting upgrade procedure. It is important to consider the capital costs together with the operational costs to ensure that an overall economic solution results.

8.2 The step by step procedures to calculate the payback period for each lighting upgrade are as follows (examples are shown in Annex C).

a) Determine the current operational cost of existing energy use in KWh.

b) Estimate the current maintenance cost for existing lighting system and labour usage requirement.

c) Calculate the cost for new lighting system that shall consist of product and installation.

d) Calculate the projected annual saving for new lighting system.

e) Calculate the projected annual saving in maintenance cost.

f) Calculate the total annual saving and payback period.

9. Lighting installation

9.1 All electrical installations and equipment including for LED lighting shall comply with the *Electricity Supply Act 1990 (Act 447)* and *Electricity Regulations 1994*.

9.2 All electrical installation works shall be carried out by electrical contractors registered with the Energy Commission.

9.3 All electrical installations and equipment, in addition to compliance with relevant product standards, shall comply with the following standards and requirements:

a) Non-residential or similar installation - MS 1936;

b) residential or similar installation - MS 1979;

c) MS IEC 60364;

d) MS IEC 60038;

e) nominal voltage: Single or Three Phase: 230/400 V –6 %, +10 %, 50 Hz + 1; and

f) earthing system.

9.4 All lighting wiring works shall be carried out in accordance with the guidelines for electrical wiring in residential buildings published by Energy Commission.

9.5 For LED lamps retrofitting, three different types of installation may be followed (see Figure 5).

a) Type 1: The lamp uses the existing fluorescent ballast and it also has an internal controlgear (driver). One downside of Type 1 lamps is that they are powered from the existing luminaire's ballast. The age and electrical design of the ballast can lower the potential energy efficiency and reliability of the system.

b) Type 2: This type of lamp involves rewiring the 230 AC volt line voltage directly to the sockets and, as such, has the highest safety risk. Because of the high voltage, the shock could cause serious injury or death. The installer is required to put a label on the fixture indicating that the fixture has been modified, that a potential electrical shock hazard exists, and that the lamp should not be replaced with a fluorescent lamp.

c) Type 3: The lamp uses line voltage, but electrical connections to the ballast are terminated and the line voltage is connected to an external controlgear that powers the LED.

9.6 The installation process shall ensure that systems are properly commissioned prior to full operation. Installation oversight is critical to avoiding complications during the retrofit process, and commissioning by a trained professional will ensure that the system is performing effectively and occupants are comfortable.

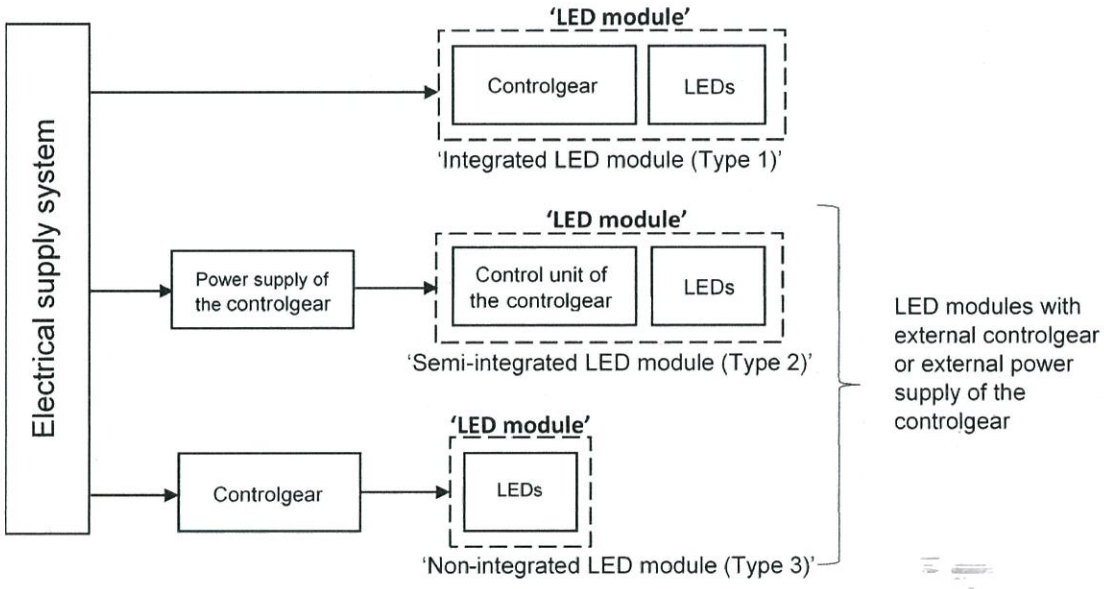

Figure 5. Types of LED modules
[Source: MS IEC 62717]

10. Lighting performance verification

Verification of the lighting installation shall be by measurement, calculation or inspection of data. The procedure shall be in accordance with MS ISO 8995.

10.1 Illuminance

The illuminance shall be measured at specified points on the relevant areas. The readings shall not be less than that calculated for the point.

The maintained illuminance shall be calculated from measured values on the same grid points as used in the design calculation and the value shall not be less than that specified for the task.

For repeat measurements, the same points shall be used.

10.2 Unified glare rating (UGR)

The manufacturer should provide authenticated UGR value in the data sheet of each luminaire which can help designers to determine how likely a luminaire and its operation in a room are to cause discomfort to those around it, taking account of the eye level and direction of view of the user.

The installation shall be in accordance with the design specifications.

10.3 Colour rendering index (R_a)

Authenticated R_a data shall be provided for the lamps used in the scheme by the manufacturer of the lamps. The lamps shall be checked against the design specifications and shall have an R_a not less than the value specified in the design.

10.4 Colour appearance (T_{cp})

Authenticated T_{cp} value shall be provided for the lamps in the scheme by the manufacturer of the lamps. The T_{cp} value of the lamps shall not be less than the value specified in the design.

10.5 Total luminous flux

The manufacturer of the luminaire shall provide these data based on total luminous flux.

10.6 Tolerances in measurements

The acceptable tolerance for all measurements shall be ±10 %.

11. Maintenance and warranty

11.1 Maintenance

11.1.1 The new upgraded lighting installation systems shall be periodically monitored, tuned and maintained to ensure that they continue to function correctly.

11.1.2 Maintenance personnel, facility managers and the office occupants themselves should be involved in the installation process and trained on system operation. Engaging end users throughout the entire process reduces misunderstandings that can derail projects, ensures a smooth transition and creates project advocates.

11.1.3 A comprehensive maintenance schedule should be prepared to include frequency of lamp replacement, luminaire and room surface cleaning intervals and cleaning method.

11.2 Warranty

Warranties of the product shall cover the performance and operation of the system. The colour shift and lumen depreciation shall be included.

Annex A
(normative)

Example of worksheets

Section	Lighting								
	Type of lamp *(incande scent/ halogen/CFL)*	**# of lamps**	**System wattage**	**# of hours used per yr** *(hrs per day x 365 days)*	**Colour Rendering Index (CRI)**	**Correlated Colour Temperature (CCT)**	**Illuminance**	**Flicker**	**Notes** *(are any lamps either too dim/bright for their application, is shade/cover size adequate, are lamps in room necessary?)*
Overhead/ceiling fixture									
Table/desk/fixture									
Floor lamp/torchier fixture									
Other fixture									
Type:									
Other fixture									
Type:									
Other fixture									
Type:									
Other fixture									
Type:									
Other fixture									
Type:									
Other fixture									
Type:									
Total yearly kWh for using all lamps before retrofit									
Total yearly kWh saved from switching to CFLs									

Figure A.1. Example of lighting audit worksheet

	ESTIMATED Savings All Program Rules	ESTIMATED Incentive All Program Rules Apply
kWh	0	Need Project cost
kWh	0.00	Need Project cost

	Building Info - Required				Baseline/Existing Lighting - Optional for New					Proposed Lighting - Required								Estimated Savings	
	Area of Building (i.e. Warehouse or Office)	Area Type - Choose from dropdown	Description of Area Operating Hours	Area Hours of Operation Per Year	Description/ Model No. of Lighting	Wattage of Existing Fixtures	Number of Fixtures	Number of Lamps per Fixture	Materials Cost per Line Item	Complete Fixture Model number	Product Qualification	DLC Product ID#	Wattage of New Fixtures	Number of Fixtures	Number of lamps per Fixture	Materials Cost per Line Item	Labour Cost per Line Item	kW	kWh
	Example - Office #205	Office	10 hours/day, 5 days/week, 50 weeks/year	2,500	4ft 4L T8	112	10	4	RM500.00	ABC-LED-32WFIXT	DLC	ZYX321	32	10	1	RM1,500.00	RM250.00	0.44	2.42
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			

Figure A.2. Example of lighting inventory worksheet

Annex B
(normative)

Schedule of lighting requirements

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
1. General building areas					
Entrance halls	100	22	60	0.40	
Lounges	200	22	80	0.40	
Circulation areas and corridors	100	28	40	0.40	At exits and entrances provide a transition zone and avoid sudden changes
Stairs, escalators, travellators	150	25	40	0.40	
Loading ramps/bays	150	25	40	0.40	
Canteens	200	22	80	0.40	
Rest rooms	100	22	80	0.40	
Rooms for physical exercise	300	22	80	0.40	
Cloakrooms, washrooms, bathrooms, toilets	200	25	80	0.40	
Sick bay	500	19	80	0.60	
Rooms for medical attention	500	16	90	0.60	T_{cp} at least 4 000 K
Plant rooms, switch gear rooms	500	25	60	0.40	
Post room, switchboard	500	19	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_0)	Remarks
Store, stockrooms, cold store	100	25	60	0.40	200 lux if continuously occupied
Dispatch packing handling areas	300	25	60	0.60	
Control station	150	22	60	0.60	200 lux if continuously occupied
2. Agriculture building					
Loading and operating of goods handling equipment and machinery	200	25	80	0.40	
Building for livestock	50	28	40	0.40	
Sick animal pens, calving stalls	200	25	80	0.60	
Feed preparation, dairy, utensil washing	200	25	80	0.60	
3. Bakeries					
Preparation and baking	300	22	80	0.60	
Finishing, glazing, decorating	500	22	80	0.70	
4. Cement, concrete and bricks industry					
Drying	50	28	20	0.40	Safety colours shall be recognisable
Preparation of materials, work on kilns and mixers	200	28	40	0.40	
General machine work	300	25	80	0.60	
Rough forms	300	25	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
5. Ceramics and glass industry					
Drying	50	28	20	0.40	
Preparation, general machine work	300	25	80	0.60	
Enamelling, rolling, pressing, shaping simple parts, glazing, glass blowing	300	25	80	0.60	
Grinding, engraving, glass polishing, shaping precision parts, manufacture of glass instruments	750	19	80	0.70	
Decorative work	500	19	80	0.70	
Grinding of optical glass, crystal hand grinding and engraving, work on average goods	750	16	80	0.70	
Precision work e.g. decorative grinding, hand painting	1 000	16	90	0.70	T_{cp} at least 4 000 K
Manufacture of synthetic precious stones	1 500	16	90	0.70	T_{cp} at least 4 000 K
6. Chemicals, plastics and rubber industry					
Remote operated processing installations	50	-	20	0.40	Safety colours shall be recognisable
Processing installations with limited manual intervention	150	28	40	0.40	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_0)	Remarks
Constantly manned work places in processing installations	300	25	80	0.60	
Precision measuring rooms, laboratories	500	19	80	0.60	
Pharmaceutical production	500	22	80	0.60	
Tyre production	500	22	80	0.60	
Colour inspection	1 000	16	90	0.70	T_{cp} at least 6 500 K
Cutting, finishing, inspection	750	19	80	0.70	
7. Electrical industry					
Cable and wire manufacture	300	25	80	0.60	
Winding:					
- large coils	300	25	80	0.60	
- medium sized coils	500	22	80	0.60	
- small coils	750	19	80	0.70	
Coil impregnating	300	25	80	0.60	
Galvanising	300	25	80	0.60	
Assembly work:					
- rough e.g. large transformers	300	25	80	0.60	
- medium e.g. switchboards	500	22	80	0.60	
- fine e.g. telephones	750	19	80	0.70	
- precision e.g. measuring equipment	1 000	16	80	0.70	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Electronic workshops, testing, adjusting	1 500	16	80	0.70	
8. Food industry					
Workplaces and zones in breweries, malting floor, for washing, barrel filling, cleaning, sieving, peeling, cooking in preserve and chocolate factories, work places and zones in sugar factories, for drying and fermenting raw tobacco, fermentation cellar	200	25	80	0.40	
Sorting and washing of products, milling, mixing, packing	300	25	80	0.60	
Work places and zones in slaughter houses, butchers, dairies mills, on filtering floor, in sugar refineries	500	25	80	0.60	
Cutting and sorting of fruit and vegetables	300	25	80	0.60	
Manufacture of delicatessen foods, kitchen	500	22	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Manufacture work of cigars and cigarettes	500	22	80	0.60	
Inspection of glasses and bottles, product control, trimming, sorting decoration	500	22	80	0.60	
Laboratories	500	19	80	0.60	
Colour inspection	1 000	16	90	0.70	T_{cp} at least 4 000 K
9. Foundries and metal casting plants					
Man-size underfloor tunnels, cellars, etc.	50	28	20	0.40	Safety colours shall be recognisable
Platforms	100	25	40	0.40	
Sand preparation	200	25	80	0.40	
Dressing room	200	25	80	0.40	
Workplaces at cupola and mixer	200	25	80	0.40	
Casting bay	200	25	80	0.40	
Shake out areas	200	25	80	0.40	
Machine moulding	200	25	80	0.40	
Hand and core moulding	300	25	80	0.60	
Die casting	300	25	80	0.60	
Model building	500	22	80	0.60	
10. Hairdressers					
Hairdressing	500	19	90	0.60	
11. Jewellery manufacturing					
Working with precious stones	1 500	16	90	0.70	T_{cp} at least 4 000 K
Manufacture of jewellery	1 000	16	90	0.70	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Watch making (manual)	1 500	16	80	0.70	
Watch making (automatic)	500	19	80	0.60	
12. Laundries and dry cleaning					
Goods in, marking and sorting	300	25	80	0.60	
Washing and dry cleaning	300	25	80	0.60	
Ironing, pressing	300	25	80	0.60	
Inspection and repairs	750	19	80	0.70	
13. Leather industry					
Work on vats, barrels, pits	200	25	40	0.40	
Fleshing, skiving, rubbing, tumbling of skins	300	25	80	0.40	
Saddlery work, shoe manufacture stitching, sewing, polishing, shaping, cutting and punching	500	22	80	0.60	
Sorting	500	22	90	0.60	T_{cp} at least 4 000 K
Leather dyeing (machine)	500	22	80	0.60	
Quality control	1 000	19	80	0.70	
Colour inspection	1 000	16	90	0.70	T_{cp} at least 4 000 K
Shoe making	500	22	80	0.60	
Glove making	500	22	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
14. Metal working and processing					
Open die forging	200	25	60	0.60	
Drop forging, welding, cold forming	300	25	60	0.60	
Rough and average machining: tolerance > 0.1 mm	300	22	60	0.60	
Precision machining, grinding: tolerance < 0.1 mm	500	19	60	0.70	
Scribing, inspection	750	19	60	0.70	
Wire and pipe drawing shapes	300	25	60	0.60	
Plate machining ≥ 5 mm	200	25	60	0.60	
Sheet metalwork < 5 mm	300	22	60	0.60	
Tool making, cutting equipment manufacture	750	19	60	0.70	
Assembly:					
- rough	200	25	80	0.60	
- medium	300	25	80	0.60	
- fine	500	22	80	0.60	
- precision	750	19	80	0.70	
Galvanising	300	25	80	0.60	
Surface preparation and painting	750	25	80	0.70	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Tool, template and jig making, precision mechanics, micro-mechanics	1 000	19	80	0.70	
15. Paper industry					
Pulp mills, edge runners	200	25	80	0.40	
Paper manufacture and processing, paper and corrugating machines, cardboard manufacture	300	25	80	0.60	
Standard book binding work e.g. folding, sorting, gluing, cutting, embossing and sewing	500	22	60	0.60	
16. Power stations					
Fuel supply plant	50	28	20	0.40	Safety colours shall be recognisable
Boiler house	100	28	40	0.40	
Machine halls	200	25	80	0.40	
Auxiliary rooms e.g. pump rooms, condenser rooms, switchboard, etc.	200	25	60	0.40	
Control rooms	500	16	80	0.70	1. Control panels are often vertical 2. Dimming may be required

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
17. Printers					
Cutting, gilding, embossing, block engraving, work on stones and platens, printing machines, matrix making	500	19	80	0.60	
Paper sorting and hand printing	500	19	80	0.60	
Type setting, retouching, lithography	1 000	19	80	0.70	
Colour inspection in multi-coloured printing	1 500	16	90	0.70	T_{cp} 5 000 K
Steel and copper engraving	2 000	16	80	0.70	
18. Iron and steel works					
Production plants without manual intervention	50	28	20	0.40	Safety colours shall be recognisable
Production plants with occasional manual operation	150	28	40	0.40	
Production plants with continuous manual operation	200	25	80	0.60	
Slab store	50	28	20	0.40	Safety colours shall be recognisable
Furnace	200	25	20	0.40	Safety colours shall be recognisable
Mill train, coiler, shear line	300	25	40	0.60	
Control platforms, control panels	300	22	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Test, measurement and inspection	500	22	80	0.60	
Underfloor man-sized tunnels belt section, cellars, etc.	50	28	20	0.40	Safety colours shall be recognisable
19. Textile industry					
Workplace and zones in baths, bale opening	200	25	60	0.60	
Carding, washing, ironing, drawing combing, sizing, card cutting, pre-spinning, jute and hemps spinning	300	22	80	0.60	
Spinning, plying, reeling, winding warping, weaving, braiding, knitting	500	22	80	0.60	Prevent stroboscopic effect
Sewing, fine knitting, taking up stitches	750	22	90	0.70	
Manual design, drawing patterns	750	22	90	0.70	T_{cp} at least 4 000 K
Finishing, dyeing	500	22	80	0.60	
Drying room	100	28	60	0.40	
Automatic fabric printing	500	25	80	0.60	
Burling, picking, trimming	1 000	19	80	0.70	
Colour inspection, fabric control	1 000	16	90	0.70	T_{cp} at least 4 000 K

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Invisible mending	1 500	19	90	0.70	T_{cp} at least 4 000 K
Hat manufacturing	500	22	80	0.60	
20. Vehicle construction and repair					
Body work and assembly	500	22	80	0.60	
Painting, spraying chamber, polishing chamber	750	22	80	0.70	
Painting: touch-up, inspection	1 000	16	90	0.70	T_{cp} at least 4 000 K
Upholstery manufacture (manned)	1 000	19	80	0.70	
Final inspection	1 000	19	80	0.70	
General vehicle services, repair and testing	300	22	80	0.60	Consider local lighting
21. Wood working and furniture industry					
Automatic processing e.g. drying plywood manufacturing	50	28	40	0.40	
Steam pits	150	28	40	0.40	
Saw frame	300	25	60	0.60	Prevent stroboscopic effects
Work at joiner's bench, gluing assembly	300	25	80	0.60	
Polishing, painting, fancy joinery	750	22	80	0.70	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking	500	19	80	0.60	Prevent stroboscopic effects
Selection of veneer woods, marquetry, inlay work	750	22	90	0.70	T_{cp} at least 4 000 K
Quality control	1 000	19	90	0.70	T_{cp} at least 4 000 K
22. Offices					
Filing, copying, circulation, etc.	300	19	80	0.40	
Writing, typing, reading, data processing	500	19	80	0.60	
Technical drawing	750	16	80	0.70	
CAD workstation	500	19	80	0.60	
Conference and meeting rooms	500	19	80	0.60	Lighting should be controllable
Reception desk	300	22	80	0.60	
Archives	200	25	80	0.40	
23. Retailing					
Sales area small	300	22	80	0.40	
Sales area large	500	22	80	0.60	
Till area	500	19	80	0.60	
Wrapper table	500	19	80	0.60	
24. Restaurants and hotels					
Reception/cashier desk, porters desk	300	22	80	0.60	
Kitchen	500	22	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Restaurant, dining room, function room	200	22	80	-	The lighting should be designed to create intimate atmosphere
Self-service restaurant	200	22	80	0.40	
Buffet	300	22	80	0.60	
Conference rooms	500	19	80	0.60	Lighting should be controllable
Corridors	100	25	80	0.40	During night time lower levels are acceptable
25. Places of entertainment					
Theatres and concert halls	200	22	80	0.50	
Multipurpose halls	300	22	80	0.60	
Practice rooms, dressing rooms	300	22	80	0.60	Glare free mirror lighting for make-up required
Museums (general)	300	19	80	-	Lighting to suit the display requirements, protect against radiation effects
26. Libraries					
Bookshelves	200	19	80	0.40	
Reading area	500	19	80	0.60	
Counters	500	19	80	0.60	
27. Public car parks (indoor)					
In/out ramps (during the day)	300	25	40	0.40	Safety colours shall be recognisable

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_0)	Remarks
In/out ramps (at night)	75	25	40	0.40	Safety colours shall be recognisable
Traffic lanes	75	25	40	0.40	Safety colours shall be recognisable
Parking areas	75	28	40	0.40	A high vertical illuminance increases recognition of people faces, therefore the feeling of safety
Ticket office	300	19	80	0.60	1. Avoid reflection in the windows 2. Prevent glare from outside
28. Educational buildings					
Play school room	300	19	80	0.40	
Nursery class	300	19	80	0.40	
Nursery craft room	300	19	80	0.60	
Classrooms, tutorial rooms	300	19	80	0.60	Lighting should be controllable
Classrooms for evening classes and adult education	500	19	80	0.60	
Lecture hall	500	19	80	0.60	Lighting should be controllable
Black board	500	19	80	0.70	Prevent specular reflection
Demonstration table	500	19	80	0.70	In lecture hall 750 lux
Art and craft rooms	500	19	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Art rooms in art schools	750	19	90	0.70	T_{cp} > 5 000 K
Technical drawing rooms	750	16	80	0.70	
Practical rooms and laboratories	500	19	80	0.60	
Teaching workshop	500	19	80	0.60	
Music practice rooms	300	19	80	0.60	
Computer practice rooms	500	19	80	0.60	
Language laboratory	300	19	80	0.60	
Preparation rooms and workshops	500	22	80	0.60	
Student common rooms and assembly halls	200	22	80	0.40	
Teachers rooms	300	22	80	0.60	
Sport halls, gymnasium and swimming pool	300	22	80	0.60	For public access facilities see CIE 58 and CIE 63
29. Health care premises					
Waiting rooms	200	22	80	0.40	Illuminance at floor level
Corridors: during the day	200	22	80	0.40	Illuminance at floor level
Corridors: during the night	50	22	80	0.40	Illuminance at floor level
Day rooms	200	22	80	0.60	Illuminance at floor level
Staff office	500	19	80	0.60	
Staff rooms	300	19	80	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_0)	Remarks
Wards:					
- General lighting	100	19	80	0.40	Illuminance at floor level
- Reading lighting	300	19	80	0.70	
- Simple examination	300	19	80	0.60	
Examination and treatment	1 000	19	90	0.70	
Night lighting, observation lighting	5	19	80	-	
Bathrooms and toilets for patients	200	22	80	0.40	
Examination room general	500	19	90	0.60	
Ear and eye examination	1 000	-	90	-	Local examination luminaire
Reading and colour vision test with vision charts	500	16	90	0.70	
Scanners with image enhancers and television systems	50	19	80	-	
Dialysis rooms	500	19	80	0.60	
Dermatology rooms	500	19	90	0.60	
Endoscopy rooms	300	19	80	0.60	
Plaster rooms	500	19	80	0.60	
Medical baths	300	19	80	0.60	
Massage and radiotherapy	300	19	80	0.60	
Pre-op and recovery rooms	500	19	90	0.60	
Operating theatre	1 000	19	90	0.60	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Operating cavity	Special	-	-	-	$\overline{E_m}$ = 10 000 lux to 100 000 lux
Intensive care					
- General lighting	100	19	90	0.60	At floor level
- Simple examinations	300	19	90	0.60	At bed level
- Examination and treatment	1 000	19	90	0.70	At bed level
- Night watch	20	19	90	-	
Dentists					
- General lighting	500	19	90	0.60	Lighting should be glare free for the patient
- At the patient	1 000	-	90	0.70	Local examination luminaire
- Operating cavity	5 000	-	90	-	Values higher than 5 000 lux may be required
- White teeth matching	5 000	-	90	-	T_{cp} ≥ 6 000 K
Colour inspection (laboratories)	1 000	19	90	0.70	T_{cp} ≥ 5 000 K
Sterilisation rooms	300	22	80	0.60	
Disinfection rooms	300	22	80	0.60	
Autopsy room and mortuaries	500	19	90	0.60	
Autopsy table and dissecting table	5 000	-	90	-	Values higher than 5 000 lux may be required

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(continued)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_0)	Remarks
30. Airports					
Arrival and departure halls, baggage claim areas	200	22	80	0.40	
Connecting areas, escalators, travellators	150	22	80	0.40	
Information desks, check-in desks	500	19	80	0.70	
Customs and passport control desks	500	19	80	0.70	Vertical illuminance is important
Waiting areas	200	22	80	0.40	
Luggage store rooms	200	28	60	0.40	
Security check areas	300	19	80	0.60	
Air traffic control tower	500	16	80	0.60	1. Lighting should be dimmable 2. Glare from daylight should be avoided
Air traffic rooms	500	16	80	0.60	Lighting should be dimmable
Testing and repair hangars	500	22	80	0.60	
Engine test areas	500	22	80	0.60	
Measuring areas in hangars	500	22	80	0.60	
Platforms and passenger subways (underpass)	50	28	40	0.50	

Table B.1. Schedule of interiors (areas) tasks and activities with specification of illuminance, glare limitation, colour quality and uniformity *(concluded)*

Type of interior, task or activity	Maintained illuminance ($\overline{E_m}$, lux)	Limiting unified glare rating (UGR_L)	Minimum colour rendering index (R_a)	Uniformity (U_o)	Remarks
Ticket hall and concourse	200	28	40	0.50	
Ticket and luggage offices and counters	300	19	80	0.50	
Waiting rooms	200	22	80	0.40	
31. Mosques, churches, synagogues and temples					
Body of building	100	25	80	-	
Chair, altar, pulpit	300	22	80	-	

Annex C
(normative)

Payback period analysis

C.1 General

Accurately estimating a payback period for an LED lighting upgrade requires gathering key information. First, gather data regarding the existing lighting system and lamps, including:

a) the current number of lamps;

b) the wattage of the current lamps;

c) the ballast factor of current lamps;

d) the number of hours in a day lamps will be on;

e) the number of days in a week lamps will be on;

f) the current kilowatt hour rate; and

g) the annual cost of maintaining the current lighting system.

Next, gather information on the proposed new LED lighting options and get estimates on installation costs.

C.2 Calculation of current operational and maintenance cost

a) Calculate the existing energy use in kWh:

$$\frac{\text{Existing fixture quantity x fixture wattage x hours per year}}{1\,000}$$

b) Calculate the total annual energy costs:

kWh x Electricity tariff rate (RM/kWh)

c) Calculate the annual maintenance costs:

Total number of lamps x estimated annual maintenance cost

C.3 Calculation of proposed new system cost

a) Determine how much energy the proposed LED system will use in kWh:

$$\frac{\text{Proposed fixture quantity x LED fixture wattage x hours per year}}{1\ 000}$$

b) Find the total annual energy cost for the proposed LED system:

kWh x Electricity tariff rate

c) Establish the installation costs of the new system:

Proposed fixture quantity x installation cost per fixture

d) Calculate the total fixture cost:

Proposed fixture quantity x proposed fixture cost

e) Determine the total cost for the proposed LED system:

Total installation cost + total fixture cost

C.4 Calculation of projected annual saving for system upgrading - New LED system or retrofit

a) For a new system, establish the adjusted proposed system cost:

(Proposed fixture cost + proposed installation cost) – (existing fixture cost + existing installation cost)

b) For an LED retrofit system:

i) First, calculate the annual energy savings:

(Existing kWh – proposed kWh) x Electricity tariff rate

ii) To calculate the total annual savings:

(Proposed total energy cost + proposed total maintenance cost) – (existing total energy cost + existing total maintenance cost)

C.5 Calculation formula of payback period

a) For a new system, the formula is:

$$\frac{\text{New build simple payback (in years)}}{\text{annual savings (in RM)}}$$

b) For an LED retrofit system, the formula is:

$$\frac{\text{Total cost of proposed system}}{\text{annual savings (in RM)}}$$

Bibliography

[1] MS IEC 60335-1, *Household and similar electrical appliances - Safety - Part 1: General requirements*

[2] MS IEC 60598-1, *Luminaires - Part 1: General requirements and tests*

[3] MS IEC 60598-2-1, *Luminaires - Part 2: Particular requirements - Section one - Fixed general purpose luminaires*

[4] MS IEC 60598-2-2, *Luminaires - Part 2: Particular requirements - Section 2: Recessed luminaires*

[5] MS IEC 60598-2-5, *Luminaires - Part 2-5: Particular requirements - Floodlights*

[6] MS IEC 60838-1, *Miscellaneous lampholders - Part 1: General requirements and tests*

[7] MS IEC 60838-2-2, *Miscellaneous lampholders - Part 2: Particular requirements - Connectors for LED modules*

[8] MS IEC 61347-1, *Lamp controlgear - Part 1: General and safety requirements*

[9] MS IEC 61347-2-13, *Lamp controlgear - Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules*

[10] MS IEC 62031, *LED modules for general lighting - Safety specifications*

[11] MS IEC 62560, *Self-ballasted LED-lamps for general lighting services by voltage > 50 V - Safety specifications*

[12] MS IEC 62612, *Self-ballasted LED-lamps for general lighting services - Performance requirements*

[13] MS IEC 62722-1, *Luminaire performance - Part 1: General requirements*

[14] MS IEC 62722-2-1, *Luminaire performance - Part 2-1: Particular requirements for LED luminaires*

[15] MS IEC 62776, *Double-capped LED lamps designed to retrofit linear fluorescent lamps - Safety specifications*

[16] IEC TR 62778, *Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires*

[17] BS EN 12464-1, *Light and lighting - Lighting of work places - Part 1: Indoor work places*

[18] CIE 13.3-1995, *Method of measuring and specifying colour rendering of light sources*

[19] CIE S 017/E:2011, *International lighting vocabulary*

[20] CIE 40-1978, *Calculations for interior lighting - Basic method*

[21] CIE 97-1992, *Maintenance of indoor electric lighting systems*

[22] CIE 103/5-1993, *The economics of interior lighting maintenance*

[23] UL 1598C, *Standard for Light-Emitting Diode (LED) retrofit luminaire conversion kits*

[24] *The Lighting Handbook*, Zumtobel Lighting GmbH, 6th edition, April 2018

[25] *ILO Encyclopaedia of Occupational Health and Safety*, 4th Edition

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