Implementation on LED Road Lighting in Bangkok

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Abstract— *This paper presents the study on implementation of a light-emitting diode (LED) luminaire for road lighting in metropolitan area that is been responsible by the Metropolitan Electricity Authority (MEA), Thailand. The LED luminaire were carefully selected in accordance with the MEA and international standards. This is to ensure that such LED luminaire can provide the same value of illuminance as offering by existing luminaires using High Pressure Sodium (HPS) and High-pressure Mercury Vapour (HQV) lamps; but it consumes much lower power. Upon the study, the DIALux program was used to simulate the roadway illumination in several site installations of different landscapes. Various conditions were carefully selected and implemented. The illumination provided by new LED luminaire was then compared against that by the existing luminaires using HPS 250W and HQV 125W lamps. The result shows that the replacement of HPS 250W by LED 140W can reduce power consumption by 169 W/luminaire, which is accounted for 56.5 % reduction. The energy saving can be achieved by 740.22 kWh/luminaire/year, which corresponds to reduction of CO_2 of 0.444 ton/luminaire/year. Furthermore, the replacement of HQV 125W by LED 55W can also reduce power consumption by 92.7 W/luminaire, which is accounted for 64.4 % reduction. As well, the energy saving can be realized by 406.03 kWh/luminaire/year, which corresponds to reduction of CO_2 of 0.243 ton/luminaire/year. Finally, the total energy consumption and cost from the road lighting load can be effectively reduced.*

Keywords— **Road lighting, led road lighting, energy saving lamp.**

1. INTRODUCTION

Presently, a light-emitting diode (LED) technology plays an important role in everyday life; for example in TV monitor, electronic equipment monitor, traffic light, high power torchlight, lighting in building and vehicle as well as road lighting because of its advantages such as low energy conmsumption, longer lifetime, environmental friendliness and so on. It can also be applied to many application according to the user requirement and desiner. Several countries launched LED road lighting project in public area, especially the main significant street in the country. The project applied by LED application is now continuously considered for the future usage [1]. The Metropolitan Electricity Authority (MEA) takes currently consideration on LED technology in the basis of energy conservation in the metropolitan area. Therefore, there is a research project to study, implementation, and installation of LED road lighting in Bangkok [2].

In this paper, the performances of LED luminaire are compared with existing luminaires that are 250W High Pressure Sodium (HPS) and 125W High-pressure Mercury Vapour (HQV) lamps in terms of value of illuminance and energy consumption. The DIALux program was used to simulate the roadway illumination in several site installations of different landscapes. Various conditions based on MEA and international standards [3] were carefully selected and implemented. The illumination provided by new LED luminaire was then compared against that by the existing luminaires using HPS and HQV lamps. The areas in Bangkok taken into the study are Phahurat Road, Chakphet Road and Tri Phet Road, Soi Chidlom, Thetsaban Sai 1 Road.

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2. ROAD LIGHTING REQUIREMENT

2.1 MEA Road Lighting Requirement

LED road lighting replacements for existing lamps must be provided illuminance value on roadway according to MEA road lighting requirement [3] by depending on type of roadway as showed in Table 1.

Table 1. Illuminance of MEA Road Lighting Requirement [3]

Road Category	$E_{h\ ave}$ (lux)	U_h
Main Road	15	0.33
Secondary/Local Road (Road width > 6 m)	9.7	0.33
Soi (Road width < 6m)	4.3	0.33
Personal Road	6.5	0.16

$E_{h\ ave}$ = Average value of horizontal illuminance, lux
U_h = Uniformity ratio of horizontal illuminance
$U_h = E_{h\ min} / E_{h\ ave}$

2.2 MEA Road Lighting Installation Requirement

Road lighting installation in case of installed on concrete pole and without central reservation for HQV 125W and HPS 250W according to MEA drawing standard [4] based on installation requirement is shown in Table 2.

Table 2. Road Lighting Installation in Case of Installed on Concrete Pole and without Central Reservation

Configuration	HQV 125W	HPS 250W	HPS 250W
Road Width "W" (m)	3 < W < 4	7 < W < 10	10 < W < 13
Luminaire Spacing "S" (MAX.)	32 m	40 m	40 m
Arrangement	Single-Sided Fig.1	Single-Sided Fig.1	Staggered Fig.2
Boom Lenght	1.2 m	1.7 m	1.7 m

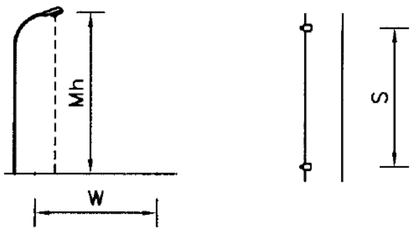

Fig.1. Single-Sided Arrangement

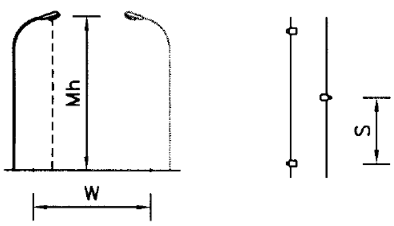

Fig.2. Staggered Arrangement

2.3 Position of Calculation Points

The calculation points according to International Commission on Illumination, CIE 140: 2000 [5] should be evenly spaced in the field of calculation and located as shown in Fig.3.

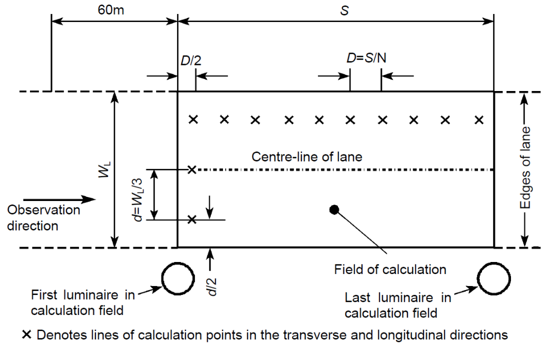

Fig.3. Position of Calculation Points in a Driving Lane.

2.3.1 In the Longitudinal Direction

The spacing (*D*) in the longitudinal direction is determined from the equation (1):

$$D = \frac{S}{N} \tag{1}$$

where: D is the spacing between points in the longitudinal direction (m); S is the spacing between luminaries in the same row (m); N is the number of calculation points in the longitudinal direction chosen such that: for S≤30 m, N=10, for S ≥ 30 m, N is the smallest integer giving D≤3m.

The first transverse row of calculation points is spaced at a distance *D*/2 beyond the first luminaire (remote from the observer).

2.3.2 In the Transverse Direction

The spacing (*d*) in the transverse direction is determined from the equation (2):

$$d = \frac{W_L}{3} \tag{2}$$

where:d is the spacing between points in the transverse direction (m); W_L is the lane width (m).

The outermost calculation points are spaced *d*/2 from the edges of the lane.

3. LED INSTALLATION AND SITE TEST

To compare the illumination performance and the electrical performance according to standard of MEA, HPS 250W with LED 140W, HQV 125W with LED 55W in case of installed on concrete pole and without central reservation was analyzed by using the ideas that include:

- Analysis of illumination performance of HPS and HQV luminaires by installation and measurement data on site test.
- Analysis of illumination performance of LED luminaire by installation and measurement data on site test.
- Analysis of illumination performance of LED luminaire by calculation using DIALux program.

3.1 Condition for Analysis and Site Test

The detail associated with analysis of illumination performance of road lighting has been shown in Table 3.

3.2 Road Lighting Installation Setting for Analysis and Site Test

Site test in the selected site was carried out in MEA distribution area of Samut Prakan province. Three luminaries were set as shown in Fig.4 and Fig.6 and the position of illuminance measurement points as shown in Fig.5 and Fig.7.

Table 3. Detial of Installation and Requirement for Calculation and Testing on Site Test

Luminaire	HPS 250W LED 140W	HQV 125W LED 55W
Arrangement	Single-Sided (Fig.1)	
Road width (m)	8	6
Number of lanes	2	2
Mounting hight (m)	8.5	7.8
Luminaire spacing (m)	40	32(40)*
Overhang (m)	2	1.5
$E_{av\,(@\,MF=0.7)}$ (lux)	15	7.5
U_0 (E_{min}/E_{av})	0.33	0.33

Note:*Luminaire spacing of testing on site test for HQV 125W and LED 55W are 40 m because of limitation of site test.

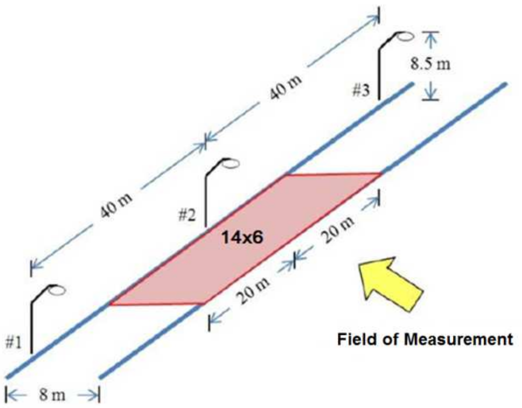

Fig.4. Road Lighting Installation for HPS 250W and LED 140W

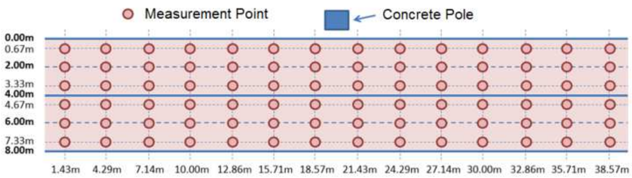

Fig.5. Position of measurement points for HPS 250W and LED 140W

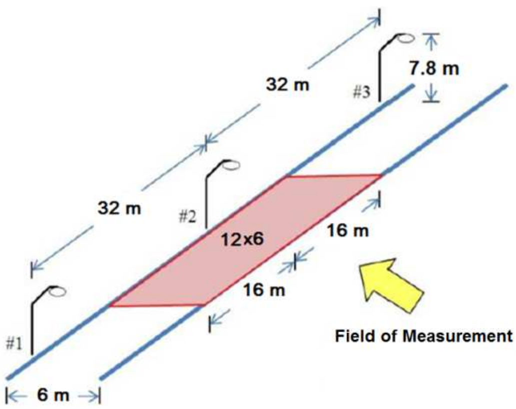

Fig.6. Road Lighting Installation for HQV 125W and LED 55W

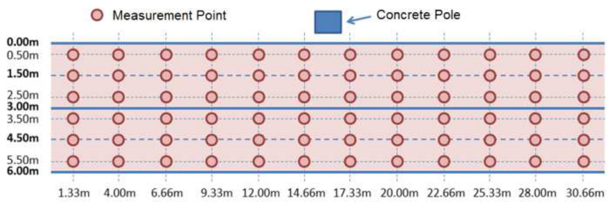

Fig.7. Positions of Measurement for HQV 125W and LED 55W

3.3 Comparative Analysis Result Between HPS 250W and LED 140W

Table 4 shows the comparative analysis result of lighting performance between HPS 250W and LED 140W by following installation and measurement data and using DIALux program on site test with a luminaire spacing as 40 m. Table 5 shows the comparative analysis result of electrical performance between HPS 250W and LED 140W by installation and measurement data on site test. Data was shown as average value per luminaire.

Table 4. Comparison of Lighting Performance between HPS 250W and LED 140W

Parameter	Requirement	HPS 250W	LED 140W
Measurement Result			
$E_{av\,(@\,MF=0.7)}$ (lux)	15	22.07	16.28
U_0 (E_{min}/E_{av})	0.33	0.05	0.29
Calculation Result			
$E_{av\,(@\,MF=0.7)}$ (lux)	15	N/A	14.67
U_0 (E_{min}/E_{av})	0.33	N/A	0.41

Table 5. Comparison of Electrical Performance between HPS 250W and LED 140W (average per luminaire)

Parameter	HPS 250W	LED 140W
Input voltage (V)	230	230
Input current (A)	1.35	0.57
Input power (W)	299	130
Power factor (lag)	0.520	0.985

The results of comparison analysis in Table 4 found that LED 140W had the illumination less than HPS 250W, while providing more than the standard criteriea of MEA, therefore, it can be used replacemented for HPS 250W. Interestingly, comparison in Table 5, LED 140W can reduce the power up to 169 W/luminaire (saving up to 56.5 %).

3.4 Comparative Analysis Result Between HQV 125W and LED 55W

Table 6 shows the comparative analysis result of lighting performance between HQV 125W and LED 55W by following installation and measurement data and using DIALux program on site test with luminaire spacing as 40m and 32m.

Table 7 shows the comparative analysis result of electrical performance between HQV 125W and LED 55W by installation and measurement data on site test. Data was shown as average value per luminaire.

Table 6. Comparison of Lighting Performance between HQV 125W and LED 55W

Parameter	Requirement	HQV 125W	LED 55W
Measurement Result (40 m)			
$E_{av(@MF=0.7)}$ (lux)	7.5	4.12	7.27
U_0 (E_{min}/E_{av})	0.33	0.302	0.151
Calculation Result (40 m)			
$E_{av(@MF=0.7)}$ (lux)	7.5	N/A	6.77
U_0 (E_{min}/E_{av})	0.33	N/A	0.246
Calculation Result (32 m)			
$E_{av(@MF=0.7)}$ (lux)	7.5	N/A	8.39
U_0 (E_{min}/E_{av})	0.33	N/A	0.401

Table 7. Comparison of Electrical Performance between HQV 125W and LED 55W (average per luminaire)

Parameter	HQV 125W	LED 55W
Input voltage (V)	230	230
Input current (A)	1.35	0.23
Input power (W)	144.0	51.3
Power factor (lag)	0.600	0.951

The results of comparison analysis in Table 6 are found that LED 55W had the illumination more than HQV 125W; therefore, it can be concluded that LED 55W can be replaced for HQV 125W. Interestingly, comparison in Table 5, LED 55W can also reduce the power up to 92.7 W/luminaire (saving up to 64.4 %).

4. REPLACEMENT OF EXISTING LAMP BY LED

4.1 Determination on Tested Area

To study and test LED road lighting, the decided areas consist of:

- Phahurat Road, Chakphet Road and Tri Phet Road: replacement of 85 luminaires HPS 250W by LED 140W (Fig.8)
- Soi Chidlom: replacement of 37 luminaires HPS 250W by LED 140W (Fig.9)
- Thetsaban Sai 1 Road: replacement of 20 luminaires HQV 125W by LED 55W (Fig.10)

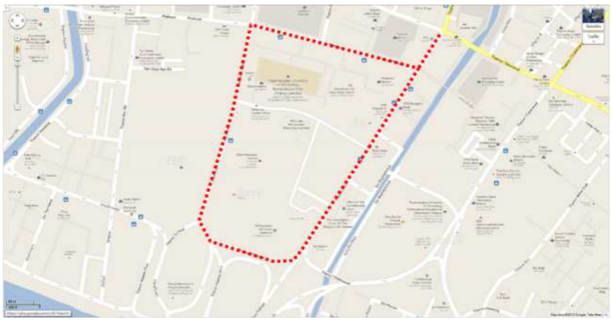

Fig.8. Map of Phahurat Road, Chakphet Road and Tri Phet Road.

Fig.9. Map of Soi Chidlom.

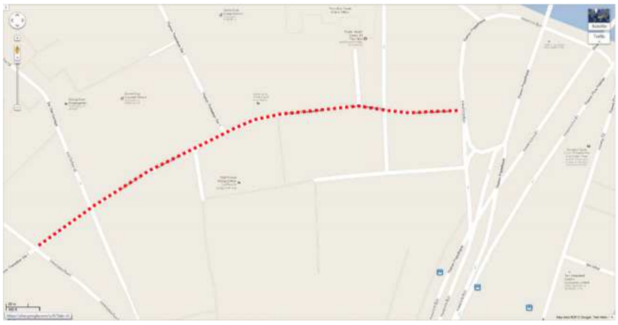

Fig.10. Map of Thetsaban Sai 1 Road.

4.2 Illumination Performances Analysis in Test Areas

Table 9 shows the comparative analysis result of lighting performance between HPS 250W and LED 140W by installation and measurement data on Phahurat Road as shown in Table 8. The results show that although LED 140W provides illumination less than HPS 250W, but it still exceeds the standard criteriea of MEA. Therefore, it can be concluded that the HPS 250W can be replaced by LED 140W.

Table 8. Road Lighting Installation Detail on Phahurat Road

Luminaire	HPS250W/ LED140W
Arrangment	Staggered
Road width (m)	14.5
Number of lanes	5
Mounting hight (m)	8.8
Luminaire spacing (m)	36/32
Overhang (m)	2

Table 9. Comparison of Lighting Performance between HPS 250W and LED 140W on Phahurat Road

Parameter	Requirement	HPS 250W	LED 140W
$E_{av\,(@\,MF=0.7)}$ (lux)	15	37.7	30.7
U_0 (E_{min}/E_{av})	0.33	0.35	0.42

The comparative analysis result of lighting performance between HQV 125W and LED 55W by installation and measurement data on Thetsaban Sai 1 Road as shown in Table 10. It is found that the LED 55W has more illumination than the HQV 125W. Therefore, it can be concluded that the HQV 125W can be replaced by the LED 55W.

Fig.11. Illumination Comparison between HPS 250W (top) and LED 140W (bottom) on Phahurat Road.

Fig.12. Illumination Comparison between HQV 125W (top) and LED 55W (bottom) on Thetsaban Sai 1 Road.

Table 10. Road Lighting Installation Detail on Thetsaban Sai 1 Road

Luminaire	HQV 125W/ LED 55W
Arrangment	Single-Sided
Road width (m)	5
Number of lanes	2
Mounting hight (m)	6.5
Luminaire spacing (m)	33
Overhang (m)	1.5

Table 11. Comparision of Lighting Performance between HQV 125W and LED 55W on Thetsaban Sai 1 Road

Parameter	Requirement	HQV 125W	LED 55W
$E_{av\,(@\,MF=0.7)}$ (lux)	7.5	8.7	15.5
U_0 (E_{min}/E_{av})	0.33	0.25	0.29

4.3 Energy Saving and CO2 Reduction Analysis

Table 12 shows the energy usage by the HPS 250W as compared to replacement by the LED 140W in kWh/luminaire/year. The results show that LED 140W can save energy up to 740.22 kWh/luminaire/year which in turn reduces CO_2 emission by 0.444 ton/luminaire/year. Thus, if one-hundred of LED 140W are installed, the energy will be saved 74,022 kWh/year and can reduce CO_2 emission by 44.413 ton/year.

Table 13 shows the energy usage by the HQV 125W as compared to replacement by the LED 55W in kWh/luminaire/year. The results indicate that using LED 55W can save energy up to 402.03 kWh/luminaire/year which in turn reduces CO_2 emission by 0.243 ton/luminaire/year. Thus, if one-hundred of LED 55W are installed, the energy will be saved 40,603 kWh/year and can reduce CO_2 emission by 24.362 ton/year.

Table 12. Energy Consumption in kWh/luminaire/year of Replacement of Existing HPS 250W by LED 140W

Parameter	HPS 250W	LED 140W
Power Consumption (W)	299	130
kWh/year	299x4,380/1,000 = 1,309.62	130x4,380/1,000 = 569.40
Energy Saving (kWh)	N/A	1,309.62 – 569.40 = 740.22
CO_2 Emission (kg/year)	1,309.62x0.6 = 785.77	569.40x0.6 = 341.64
CO_2 Reduction (kg/year)	N/A	785.77 – 341.64 = 444.13

Note: Average value of CO_2 emissions in Thailand is 563.52 g/kWh or approximate to 0.6 kg/kWh [6]

Table 13. Energy Consumption in kWh/luminaire/year of Replacement of Existing HQV 125W by LED 55W

Parameter	HQV 125W	LED 55W
Power Consumption (W)	144	51.3
kWh/year	144x4,380/1,000 = 630.72	51.3x4,380/1,000 = 224.69
Energy Saving (kWh)	N/A	630.72 – 224.69 = 406.03
CO_2 Emission (kg/year)	630.72x0.6 = 378.43	244.69x0.6 = 134.81
CO_2 Reduction (kg/year)	N/A	378.43 – 143.81 = 243.62

5. ECONOMIC ANALYSIS AND PAYBACK PERIOD

Economic analysis takes into account the energy savings and the cost of the investment of the LED luminaires. Finding a simple payback period can be calculated using the following formula:

$$Payback\ period = \frac{Investment\ cost\ of\ the\ LED\ luminaire}{Evergy\ saving\ cost\ per\ year} \quad (3)$$

The results in Table 14 are found that the payback period for replacement of HPS 250W by LED 140W is 8.57 year and for replacement of HQV 125W by LED 55W is 13.36 year. However, the payback period are depends on energy charge and investment cost.

Table 14. Calculate the simple payback period for this project

Parameter	LED 140W	LED 55W
Energy Saving (kWh/luminaire/year)	740.22	406.03
Energy Charge (THB/kWh)**	3.2532	3.2532
Energy Saving Cost (THB/luminaire/year)	2,408.08	1,320.90
Investment Cost (THB/luminaire)**	20,651.00	17,655.00
Payback Period (year)	8.57	13.36

Note: ** Data in December 2012

6. CONCLUSION

Results associated with the replacement of existing lamp by LED can be summarized as below:

a. LED road lighting 140W can be replaced for HPS 250W. Moreover, LED road lighting 140W can reduce the power up to 169 W/luminaire or might save energy up to 56.6 %.

b. LED 140W replacement for HPS 250W can save energy up to 740.22 kWh/luminaire/year and can reduce CO_2 emission by 0.444 ton/luminaire/year.

c. LED road lighting 55W can be replaced for HQV 125W, Moreover, LED road lighting 55W can reduce the power up to 92.7 W/luminaire or might save energy up to 64.4 %.

d. LED 55W replacement for HQV 125W can save energy up to 406.03 kWh/luminaire/year and can reduce CO_2 emission by 0.243 ton/luminaire/year.

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