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A Brand New World: Impacts Study of the Background Luminance and Illumination Level on Measuring of LED Billboards in Taiwan

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Abstract: Based on the domestic conditions of Taiwan, this study aims to investigate and analyze the impacts of statutory nuisance from artificial light, and then to propose the related tactics and recommendations. Our research focuses on both perception of glare and flicker. The main tasks include: (1) measurements of light pollution source, (2) study on the borderline between comfort and discomfort (BCD) of human perception and cognitions to perform subjective evaluation of glare and flicker at night condition, (3) case study of the background luminance and illumination level impacts on measuring resultants of nuisance artificial light (e.g., LED billboard). In this work, we will discuss the third task only.

This study conducted a total of 4 case studies of monitoring the luminance of LED billboards, vertical and horizontal illuminance in Taipei metropolitan area and Hsinchu downtown area.

The maximum luminance of LED billboards are between 1,588 cd/m^2 and 3,029 cd/m^2, the maximum vertical illuminance at 4 measuring locations are between 17.6 lx and 96.7 lx, the maximum horizontal illuminance at 4 measuring locations are between 5.1 lx and 72.2 lx.

The minimum luminance are in the range of 0.1 cd/m^2 to 0.7 cd/m^2, while the minimum vertical illuminance at 4 measuring locations are in the range of 0.2 lx to 35.2 lx, the minimum horizontal illuminance at 4 measuring locations are between 2.0 lx and 50 lx.

The Michelson contrast modulation (Cm) of vertical illuminance at 4 measuring locations are between 49.6% and 99.3%, while the Cm of horizontal illuminance at 4 measuring locations are between 47.1% and 94.7%.

The minimum luminance is the sum of other light sources project on the turn-off LED billboard, said the background luminance, it is no impact on the luminance measuring of LED billboard. From the Michelson contrast module of vertical illuminance at 4 locations, indicated the vertical illuminance is strong influence by the environment lighting condition. The minimum vertical illuminances are separated into two groups, one is below 25 lx, and another one is above 25 lx. This result can be used as the reference classification of night time lighting environment of urban area (non-metropolitan area) and metropolitan area of Taiwan.

Key words: light pollution, background illuminance, LED billboard

1. Introduction

When astronomers discovered the main cause of degradation of the night sky observing conditions from the development of civilization and technology growth and rapid growth of the lighting, hence light pollution became one of the environmental issues of the 1970s. As confirmed something more illumination impact on other environmental permits, an international “dark sky” campaign is advocating a precautionary approach to outdoor lighting design around this issue [1].

Light pollution is defined in CNS 15015 [2], as “A collective term for describing the negative affect on

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human health and the human environment by interference or excessive radiation (including visible light, ultraviolet and infrared radiation). Outdoor lighting, light pollution is a collective term for describing the negative affect on humans, environment, astronomical observation, transport, and so forth, which is mainly due to the obtrusive light produced by the building's facade lighting, road lighting, plaza lighting, advertising lighting, sign lighting, outdoor functions and landscape lighting for stadiums and parking lots." Where "obtrusive light" is defined by CIE 150-2003 [3] as "Spill light which because of quantitative, directional, or spectral attributes in a given context, give rise to annoyance, discomfort, distraction, or a reduction in the ability to see essential information."

Electroni Cast Consultants predicts that the worldwide value of LED packaged chips used in signage/professional displays reached $1.99 billion in 2014 and forecasts that the consumption value will increase at an average annual growth rate of 11.9% to reach about $3.56 billion in 2019 [4]. Hence, the light pollution impact caused by LED-based outdoor electronic billboards may also more serious in the foreseeable future.

Based on the domestic conditions of Taiwan, our research focuses on both perception of glare and flicker for LED light sources. In last three years, we had publish our results on measurements of light pollution source (first task) [5-8] and on the study of borderline between comfort and discomfort (BCD) for human perception and cognitions to perform subjective evaluation of glare and flicker at night condition (second task) [9-11]. In 2013 we study the flicker and glare perception of LED billboard [9, 10], and proposed a method to measure the flicker and glare simultaneously in 2014 [5]. In 2014, we completed a small survey of the light pollution impact of LED billboards and other signs (Neon signs, light box signs, LED combo lamp signs) around Taipei city and Hsinchu city [6, 8], the results indicate that major impact are from LED billboard. Meanwhile, we also proposed a method to measure the flicker behaviour of LED combo [7], and modified the apparatus to apply the outdoor LED billboard and the results will publish in near future. In 2015 we proposed a method that can eliminate the background noise in outdoor luminance and illuminance measurement [8], and study the discomfort glare of LED billboard that display motion pictures and proposed a luminance BCD chart [11].

In this work, we will discuss the case study the impacts of background illumination level on measuring resultants of outdoor LED billboards (third task). There were 4 locations selected in this study, as shown in Fig. 1, two locations in Taipei City, two locations in Hsin-chu City, they are exit of Taipei MRT Da-An station, crossroad of Wuxing street and Songren road, crossroad of Hsin-Chu Central road and Dongda road, Taiwan Pavilion Expo, respectively.

2. Experimental Set-up

The experimental set-up is shown as Fig. 2, a Konica-Minolta LS-100 luminance meter was used for monitoring the luminance of LED billboard, and a Konica-Minolta T-10 illuminance meter was used for monitoring the environmental vertical illuminance and horizontal illuminance. The measurement height is set as the average pedestrian standing eye height, which is 1.5 m [12]. Luminance meter aligned with the center of LED billboard, and field of view encompassed within LED billboard. When measuring vertical illuminance, the light-receiving head facing the LED billboard along the horizontal line of sight in front, when measuring the horizontal illuminance, the light-receiving head facing the sky directly above. The luminance data of monitored LED billboard and the illuminance data are recorded by the controller through the control-lines.

3. Results and Discussion

3.1 Luminance and Illuminance Monitoring Results of Taipei MAT Da-An and Wuxing Street

The four days (July 26, July 27, Aug. 5, Aug. 8)

(a) Taipei MRT Da-An (b) Taipei Wuxing Street

(c) Hsin-Chu Central Road (d) Taiwan Pavilion Expo

Fig. 1 Images of four locations for lighting environment study: (a) Taipei Da-Aa MRT, (b) Taipei Wuxing Street, (c) Hsin-Chu Central Road, (d) Taiwan Pavilion Expo.

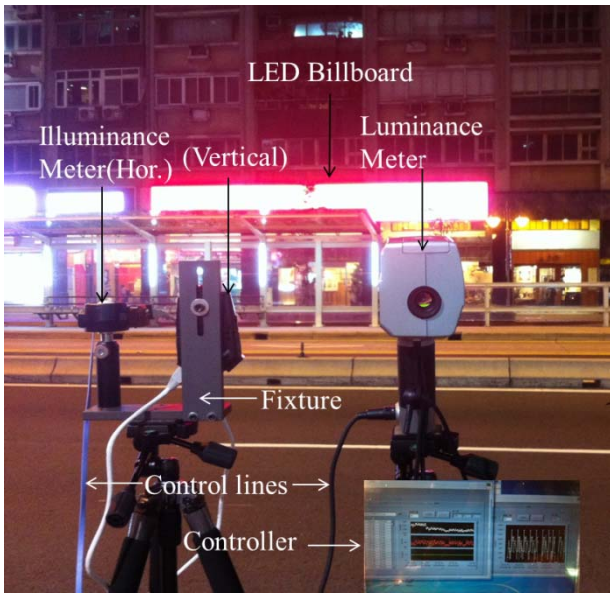


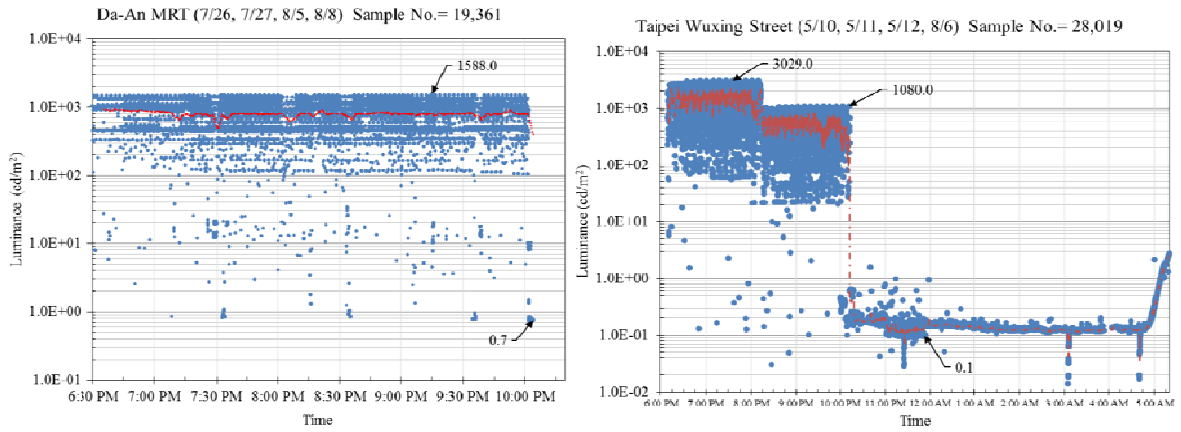
Fig. 2 Experimental set-up.

luminance distribution of LED billboard located near Taipei MRT Da-An shown in Fig. 4a, where the data recorded in the period around 6:30 PM to 10:00 PM, eliminating the measurement value is 0 cd/m^2, total number of 19,361 valid samples recorded, where blue dot is luminance, and red dash-line is moving average of luminance. We found that the maximum luminance, the 90th percentile luminance, the 50th percentile of the luminance, and the minimum luminance of the LED billboard were 1,588 cd/m^2, 1,352 cd/m^2, 826.2 cd/m^2, and ~0.7 cd/m^2, respectively. In addition, after 10:00 PM the LED billboard was off, the measured luminance was ~0.7 cd/m^2, it can be deduced that the average luminance at this metropolitan city downtown area was ~0.7 cd/m^2.

The four days (May 10, May 11, May 12, Aug. 6) luminance distribution of LED billboard located near Taipei Wuxing Street shown in Fig. 4b, where the data recorded in the period around 6:00 PM to next day 5:00 AM, eliminating the measurement value is 0 cd/m^2, total number of 28,019 valid samples recorded. We found that the maximum luminance, the 90th percentile luminance, the 50th percentile of the luminance, and

the minimum luminance of the LED billboard were 3,029 cd/m^2, 1,899 cd/m^2, 472.7 cd/m^2, and ~0.01 cd/m^2, respectively. In addition, after 12:00 PM the LED billboard was off, the measured luminance was ~0.1 cd/m^2, it can be deduced that the average luminance at this metropolitan city downtown area was ~0.1 cd/m^2.

Fig. 3 Program interface of luminance monitoring.



(a) (b)

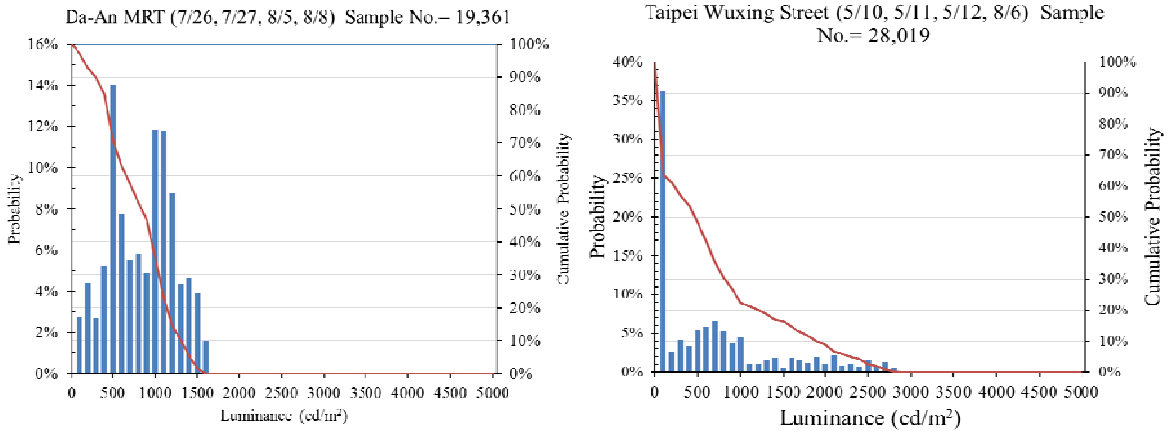
Fig. 4 Luminance distribution of LED billboard located at Taipei (a) MRT Da-An exit, (b) Wuxing Street.
Blue dot (··) luminance of LED billboard; Red dash-line (--) moving average of luminance

In Fig. 5a, the analysis showed that the cumulative probability is 0% for luminance greater than 2,000 cd/m^2, ~1.6% for luminance greater than 1,500 cd/m^2, while > 30% for luminance greater than 1,000 cd/m^2 of LED billboard located at MRT Da-An Exit. Which indicate there are >30% probability for the luminance level of LED billboard large than CIE 150-2003 E4 zone recommendation.

In Fig. 5b, the analysis showed that the cumulative probability is 8.8% for luminance greater than 2,000 cd/m^2, ~16.4% for luminance greater than 1,500 cd/m^2, while > 20% for luminance greater than 1,000 cd/m^2, of LED billboard located at Wuxing Street. Which indicate there are > 20% probability for the luminance level of LED billboard large than CIE 150-2003 E4 zone recommendation 4.

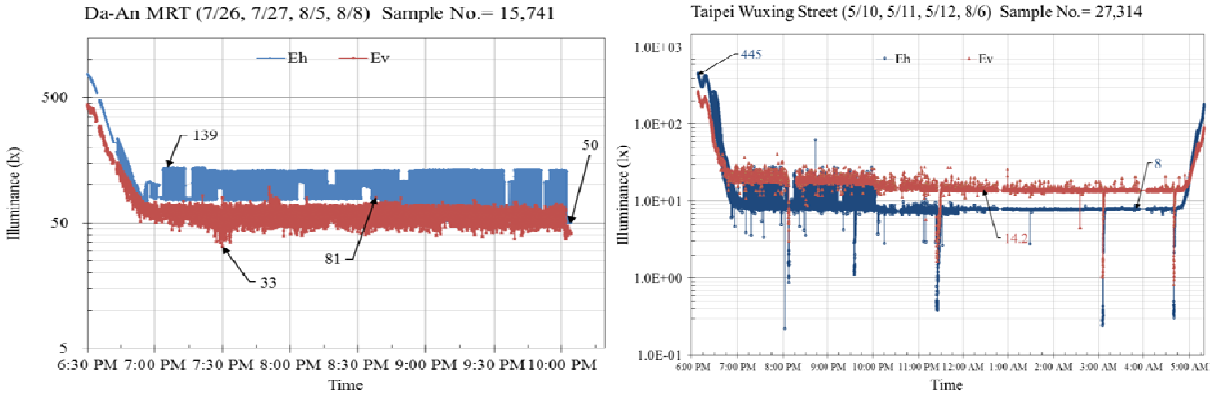
Near the exit of Taipei MRT Da-An station, the ambient illumination around 6:30 PM to 7:00 PM affected considerably by the sun. Therefore, we analyze the data, as shown in Fig. 6a, after 7:00 PM, the results showed that the maximum horizontal illuminance, the 90th percentile of horizontal

illuminance, the 50th percentile of horizontal illuminance, the minimum horizontal illuminance were 139 lx, 132.6 lx, 106.7 lx, and 50 lx at measurement location, respectively. Where the gap between the highest and lowest level of horizontal illumination is 89 lx, standard deviation of up to 28.2 lx, the reason might due to a floodlight on top of measurement location will turn-off after 8:30 PM, so that the minimum horizontal illuminance decreased. The maximum vertical illuminance, the 90th percentile of vertical illuminance, the 50th percentile of vertical illuminance, the minimum vertical illuminance values were 96.7 lx, 66.1 lx, 59.1 lx, and ~35.2 lx at measurement location, respectively. Where the highest and lowest vertical illuminance gap of 64.1 lx, and the standard deviation is 6.5 lx. In Michelson Contrast Modulation (Cm), as shown in Equation 1, the results indicate the contrast of horizontal illumination is 47.1%, and the contrast of vertical illuminance is 49.6%.



(a) (b)

Fig. 5 Cumulative probability of luminance of LED billboard located at Taipei (a) MRT Da-An exit, (b) Wuxing Street.



(a) (b)

Fig. 6 Horizontal and vertical illuminance at Taipei (a) MRT Da-an exit, (b) Wuxing Street.

$$C_m = \frac{Max - Min}{Max + Min} \quad (1)$$

Where

Max is the maximum value,

Min is the minimum value.

When analyzing illuminance data, although the vehicle passing through the space between LED billboards and illuminance meter will affect the measured vertical illuminance, and LED billboard broadcast dynamic content cause fluctuations in vertical illuminance, but the overall ambient light observed in this region, to observe the vertical illuminance is relatively stable, as shown in Fig. 6a. In addition, during the four days observation we found the

LED billboards will turn-off about 10 PM. Whereby the average horizontal illuminance observed after 10:00 PM dropped to 84.8 lx with standard deviation of 35.4 lx, while the average vertical illuminance is reduced to about 51.6 lx with standard deviation of 6.6 lx. The above values can be used as reference for future assessments of the metropolitan downtown area background light environment.

At crossroad of Taipei Wuxing Street and Songren road, due to the sun set time is around 6:30 PM in May, hence the ambient illumination around 6:00 PM to 7:00 PM affected considerably by the sun.

Therefore, we analyze the data shown in Fig. 6b from 7:00 PM to 10:00 PM, the results showed that the maximum horizontal illuminance, the 90th percentile of horizontal illuminance, the 50th percentile of horizontal illuminance, the minimum horizontal illuminance were 41 lx, 22.8 lx, 19.4 lx, and 3.1 lx at measurement location, respectively.

Where the gap between the highest and lowest level of horizontal illumination is 37.9 lx with standard deviation of 2.4 lx. The maximum vertical illuminance, the 90th percentile of vertical illuminance, the 50th percentile of vertical illuminance, the minimum vertical illuminance values were 62.9 lx, 16.8 lx, 8.9 lx, and ~0.2 lx at measurement location, respectively. Where the highest and lowest vertical illuminance gap of 62.7 lx with standard deviation of 3.9 lx. From Michelson Contrast Modulation analysis, the results indicate the contrast of horizontal illumination is 86.1%, and the contrast of vertical illuminance is 99.3%. Both the contrast are very high, it might be due to the large luminance variation of LED billboards.

When analyzing illuminance measurements, from 10:30 PM to 4:30 AM, the average horizontal illuminance is 14.1 lx, while the average vertical illuminance is decreased to about 7.7 lx. The above values can be used as reference for future assessments of the metropolitan non-downtown area background light environment.

3.2 Background Illuminance of 4 Locations in Taipei

From the results of environmental background illumination and LED billboard luminance recorded at four locations and observation the field site of four locations, we found that vertical illuminance was mainly affected by the front LED billboards or vehicle lights, while horizontal illuminance was mainly affected by the nearby street lights or complex light environment. Therefore we assuming the minimum horizontal illuminance and the minimum vertical illuminance took between 7:30 PM to about 10:00 PM deemed to be the least amount of interference measurement value. For the minimum vertical illuminance is concerned, the measured value may occur when front LED billboards play the darkest image, or occur at time of minimum temporary light sources appeared. Similarly, on the minimum horizontal illuminance is concerned, the measured value may occur in LED billboards play the darkest image.

Furthermore, the analysis of average vertical illuminance and average horizontal illuminance after LED billboards lights out, in this circumstance we can exclude the luminance affection from LED billboards, more aggregated data shown in Table 1. Where After 10:00 PM or after LED billboards lights out, the average luminance recorded (this luminance value contributions from other light sources except LED billboard under measured) at Taipei MRT Da-An, Taipei Wuxing Street, Hsinchu Central road, and Hsinchu Taiwan Pavilion Expo were 0.7 cd/m^2, 0.1 cd/m^2, 0.2 cd/m^2, and 0.2 cd/m^2, respectively.

We also found that the Michelson contrast (Cm) of vertical illuminance for 4 locations could be categorised into two ground, they are below 55% (Taipei MRT Da-An and Hsinchu Central Rd.) and above 55% (Wuxing St. and Taiwan Pavilion Expo), respectively, as shown in Fig. 7. Taipei Wuxing St. and Taiwan Pavilion Expo are belonged to large metropolitan non-downtown area and medium city non-downtown area, respectively. The lighting

environment of these two locations are relative low brightness.

Table 1 Background luminance and illuminance of four locations.

	Time	7:30PM ~ 10:00PM				10:00PM~ (or LED billboard is off)		
	Illuminance or Luminance	E_{h_min} (lx)	E_{v_min} (lx)	C_m of E_h	C_m of E_v	E_{h_ave} (lx)	E_{v_ave} (lx)	$L_{background}$(cd/m^2)
Location								
1	Taipei MRT Da-An	50	32.6	47.10%	49.60%	84.4	51.6	0.7
2	Taipei Wuxing St.	0.2	3.1	86.10%	99.30%	7.7	14.1	0.1
3	Hsinchu Central Rd.	5.8	1.5	50.50%	54.50%	3.3	7.2	0.2
4	Taiwan Pavilion Expo	2	3.7	79.90%	88.60%	2	3.7	0.2

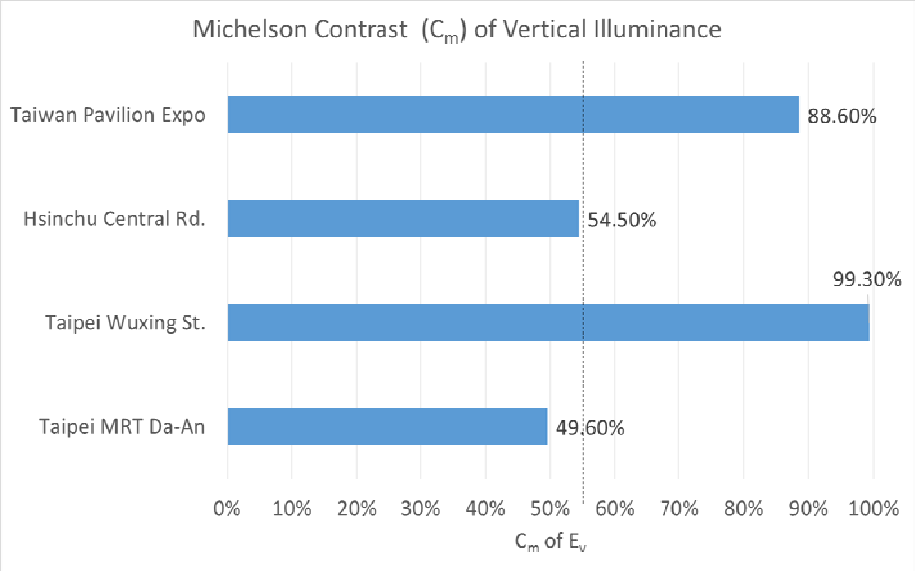


Fig. 7 Michelson contrast of Vertical Illuminance at 4 locations in Taiwan.

We found linear relationship between of horizontal illuminance and vertical illuminance shown in Table 1, the minimum vertical illuminance (Ev) is approximately 0.5607 times the minimum horizontal illuminance (Eh), (EV = 0.5607×Eh + 4.6341, R2 = 0.9825), result shown in Fig. 8. The minimum vertical illuminance distribution which can be roughly divided into two groups of higher than 25 lx and lower than 25 lx. This relationship can also be classified with reference to the large metropolitan areas as small and medium cities areas, such as the minimum vertical illuminance higher than 25 lx light environment for large metropolitan downtown areas, and the minimum vertical illuminance will be lower than 25 lx for large metropolitan non-downtown area or small and medium cities area.

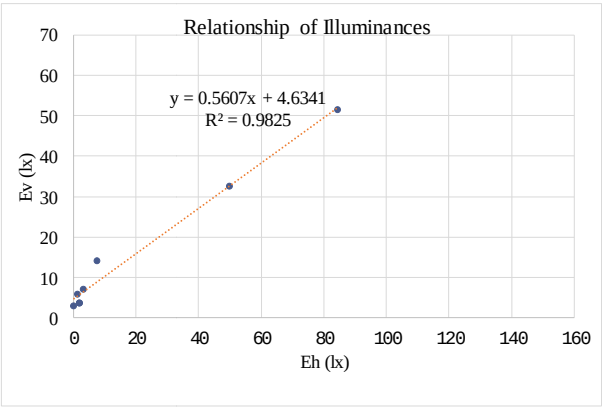


Fig. 8 Relationship between minimum vertical illuminance and minimum horizontal illuminance.

4. Summary

This study conducted a total of 4 case studies of monitoring the luminance of LED billboards, vertical

and horizontal illuminance in Taipei metropolitan area and Hsinchu downtown area. The maximum luminance of LED billboards are between 1,588 cd/m^2 and 3,029 cd/m^2, the maximum vertical illuminance at 4 measuring locations are between 17.6 lx and 96.7 lx, the maximum horizontal illuminance at 4 measuring locations are between 5.1 lx and 72.2 lx. The minimum luminance are in the range of 0.1 cd/m^2 to 0.7 cd/m^2, while the minimum vertical illuminance at 4 measuring locations are in the range of 0.2 lx to 35.2 lx, the minimum horizontal illuminance at 4 measuring locations are between 2.0 lx and 50 lx.

The Michelson contrast modulation (Cm) of vertical illuminance at 4 measuring locations are between 49.6 % and 99.3 %, while the Cm of horizontal illuminance at 4 measuring locations are between 47.1 % and 94.7 %. The minimum luminance is the sum of other light sources project on the turn-off LED billboard, said the background luminance, it is no impact on the luminance measuring of LED billboard. From the Michelson contrast modulation analysis of vertical illuminance at 4 locations, indicated the vertical illuminance is strong influence by the environment lighting condition. The minimum vertical illuminances are separated into two groups, one is below 25 lx, and the other is above 25 lx. This result can be used as the reference classification of night time lighting environment of urban area (non-metropolitan area) and metropolitan area of Taiwan.

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