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A comparative analysis of the extent of light pollution in the Cities of Mandaluyong and Pasig

Ruby-Ann Dela Cruz*

Center for Astronomy Research and Development, Department of Earth and Space Sciences, Rizal Technological University, Philippines

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Abstract

To determine the extent of light pollution in the cities of Mandaluyong and Pasig the researcher utilized the population growth data from the Philippines Statistics Agency, while the number of buildings that have been built in the two cities is taken from www.citypopulation. The radiance values which are significant in understanding light pollution in the two cities are derived from lightpollutionmap.com. Data from the VIIRS only covered the period of 2013 to 2018. One-way ANOVA (Analysis of Variance) and multiple correlations are used in this study to find out the correlations and relationships of all variables which are applied in this study. The statistical tests were run in SPSS version 25. The study reveals that areas with high levels of radiance value in Mandaluyong and Pasig share common characteristics, such as their proximity to two major thoroughfares in the Metropolitan Manila area. These two major thoroughfares both have numerous street lights and are lined on both sides by big signages and billboards lit by powerful LED spotlights, and becoming more numerous lately are huge LED billboards. In addition, both roads have heavy traffic at night. The study also determines that the type of residential setup in both cities contributes to the extent of light pollution. As the population in the two cities grows, the demand for housing, malls, and commercial establishments continues to grow. Both cities are highly urbanized and heavily light polluted. The information this paper reveals can be the basis in the creation of a drive or campaign to mitigate current and future problems in both cities pertaining to light pollution.

***Corresponding Author:** Ruby-Ann Dela Cruz ✉ rbdcruz@rtu.edu.ph

Introduction

Mandaluyong and Pasig City are two of the oldest barrios/towns in the Philippines. Both are known for their commercial and residential areas; thus, these two cities were classified as highly urbanized areas in the Philippines.

According to Mandaluyong.gov.ph (2021), Mandaluyong used to be the most backward among the municipalities due to the lack of connecting roads to the adjacent municipalities in Metropolitan Manila, by 1990, Mandaluyong was subdivided into about 39.35% Residential, 30.29% open space which is a combination of parks, road networks, cemeteries, and vacant idle land, 12.92% Industrial, 9.50% Institutional, and 7.88% Commercial. By the year 2004, 36.84 percent is Residential, 33.09 percent open space and others, 17.55 percent is Commercial, 7.18 percent is Institutional, and 5.33 percent is Industrial. In just less than a decade almost 10% there is already about a 9% increase in commercial, about 6% increase for Residential, about 3% increase in Open spaces, about 8% decrease in Industrial, about 2% decrease in Institutional land usage.

According to Pasig.gov.ph, the City of Pasig is a highly urbanized city within the heart of Metro Manila, Philippines. It has a population of 755 thousand which is about 5% of the total population of Metro Manila, according to the 2015 National Census. Its land area covers 34.32 sq. km. which comprises 30 barangays – the smallest administrative division in the Philippines. The calculated urban population density is 22,008 inhabitants per sq. km.

It also houses several business districts, shopping malls, and infrastructures that house not only shopping hubs but also restaurants and bars. Both Mandaluyong and Pasig City have varying urban characteristics, medium-scale commercial districts, heavy industries line the cities' river coasts, and low to high-density residential areas. Highly urbanized cities like Mandaluyong and Pasig are exposed to different types of pollution. The Philippines is a developing country, the cities of Mandaluyong and Pasig are just two of its many highly urbanized cities. Both cities exhibit varying amounts of light pollution and it would be helpful to measure the extent of light pollution in these cities to address the problems that may arise due to this specific pollution. The website that shows the pollution index of the cities in the Philippines is nombeio.com but surprisingly, there is no index rating for light pollution.

This is one of the pioneering studies that tackle light pollution in the Philippines. The government might be aware of the existence of light pollution and its effect, but little or no attention is being given because its existence and effects are not as obvious as compared with other existing pollution in the country. This may be the reason why both cities do not have existing programs or agendas to lessen the cause and effect of light pollution. The study will help create a standard, model, or policies for other emerging cities to follow to avoid and prevent light pollution.

One of the most groundbreaking inventions ever made was the light bulbs. Through the years it has evolved into so many variations, lit up spaces, and provided humans with a sense of security, but too much and unregulated usage of it may also give rise to many undesirable effects. The study utilized the population growth data gathered from the Philippines Statistics Agency, the numbers of buildings were gathered from www.citypopulation, and the radiance values were from the lightpollutionmap.com. These data were analyzed and treated statistically to obtain the information needed such as the extent of light pollution in the cities of Mandaluyong and Pasig. The information from this study will be the basis of the creation of a drive or campaign to mitigate current and future problems of both cities on light pollution. This study aimed to determine the extent of light pollution in the cities of Mandaluyong and Pasig by answering the following queries:

1. What is the amount of light pollution in the Cities of Mandaluyong and Pasig in terms of radiance value.
2. What is the significant relationship between the population and the number of buildings with the extent of light pollution in Mandaluyong and Pasig city.

3. What are the characteristics of observed light pollution in the Cities of Mandaluyong and Pasig from 2013-2018.
4. What policies can be drawn according to the results of the study.

This study aimed to provide a glimpse of the current conditions of light pollution in the cities of Mandaluyong and Pasig. Society will be aware of the continuous increase of population and number of establishments in their area, it will also shed important ideas on how the population growth and increase of establishments worsen the condition of light pollution in a given location. The Community can devise a system and scheme to slow down the rate of the worsening condition of light pollution in their location. The Local Government may draw up effective urban planning. The Future Researchers will be provided with useful information on the extent of light pollution in the cities of Mandaluyong and Pasig in the period of 2013 to 2018.

Materials and methods

Study Design

The descriptive research design was utilized in this study, it allowed the researcher to observe the subjects of this study without affecting its normal behavior, test, and measure a large number of samples for the quantitative part of this research. (Shuttleworth, 2018) Light pollution occurs in all of the developing and developed cities, the extent varies depending on how developed the cities are, raw data of radiance values of the cities of Mandaluyong and Pasig were used in this study. This research focused on the cities of Mandaluyong and Pasig and covered the period of 2013-2018, due to the availability of data for radiance values found in the VIIRS. This research covered the six most populated barangays and the six areas with the greatest number of buildings found in the cities of Mandaluyong and Pasig.

Data Gathering Procedure

The data for the radiance values for each city were from the lightpollutionmap.com website while population data was from https://www. citypopulation and https://psa.gov.ph, lastly, data for the number of buildings were taken from https://www.emporis.com. The missing data for the most populated barangays for 2005 to 2010 were interpolated, while the missing data for 2020 was extrapolated. The researcher then interpolated the yearly population estimate from 2010 to 2020.

Statistical Analysis

One-way ANOVA (Analysis of Variance) and multiple correlations were used to determine the correlations and relationships of all variables used in this study. The statistical tests were run in SPSS version 25.

Results and discussion

The amount of light pollution in Cities of Mandaluyong and Pasig in terms of radiance value.

The Light Pollution Map website is overlaid with images from the Visible Infrared Imaging Radiometer Suite (VIIRS). The website contains information about light pollution such as the radiance value, radiance values tell the measurement of emitted or reflected light. Color of red has a radiance value of more than 40, peach has a radiance value between 20-40, orange: 6-20, yellow: 3-6, green: 1-3, blue-green: 0.40-1, blue: 0.25-0.40 and black has a radiance value of less than 0.25. The Metro Manila area has a radiance value ranging from the red to orange markers.

Table 1 shows the radiance values of different places with the greatest number of establishments in Mandaluyong and Pasig City. Greenfield District, a commercial strip located in Mandaluyong City has the highest radiance mean value of 66.06 followed by Megamall, a commercial establishment adjacent to EDSA that has a 60.35 radiance mean value which is closely followed by Metro walk, a commercial hub located in Pasig has 63.40 radiance mean value.

Hong Soo Lim (2018) says that outdoor lighting at night is common in Korea. Moreover, the use of artificial lighting is expected to increase as the economic development grows even further, making Korea exposed to the adverse effects of artificial lighting.

The growing issue of light pollution is based on field measurements conducted in Seoul, South Korea. This measurement was done to broaden the understanding and assessment of light pollution.

The most severe forms of light pollution were found in developed urban and densely commercialized areas during the investigation.

Table 1. Radiance Value of Mandaluyong and Pasig City form 2013-2018.

City	Light Pollution	VIIRS2018	VIIRS2017	VIIRS2016	VIIRS2015	VIIRS2014	VIIRS2013	Mean Value
Mandaluyong City	Megamall	70.25	61.73	59.73	59.26	45.96	65.2	60.35
	Greenfield	73.46	71.83	70.33	68.81	56.5	55.45	66.06
	Mandaluyong City Hall	43.19	43.32	43.97	40.44	38.02	42.76	41.95
	San Felipe Neri Church	34.33	32.39	29.74	30.48	30.01	31.6	31.42
	Capitol Commons Shopping Mall	58.76	58.32	62.59	65.31	37.7	34.46	52.85
	Metrowalk	70.09	74.61	62.92	59.58	50.85	62.4	63.4
Pasig City	Pasig City hall	36.05	31.35	32.25	32.33	29.94	31.46	32.23
	Immaculate Conception Pasig Cathedral	36.05	31.35	32.25	32.33	29.94	31.46	32.23

Table 2. Barangay Population Data, Mandaluyong City and Pasig City.

City	Barangay	Year						
		1990	1995	2000	2005	2010	2015	2020
Mandaluyong City	Mauway	10,366	16,225	16,877	20,952	27065	29,103	32,174
	Highway Hills	14,511	14,262	12,131	20,417	25941	28,703	29,497
	Addition Hills	37,322	61,010	68,885	78,942	94029	99,058	102,325
Pasig City	Manggahan	24,566	59,185	32,615	53,068	83749	93,976	97,206
	Pinagbuhatan	28,446	38,811	60,205	90,796	136683	151,979	169,502
	Rosario	57,354	48,544	48,998	53,305	59766	61,920	61,765

*****source: www.citypopulation

Table 3. Interpolated and Extrapolated Barangay Population Data of Mandaluyong City and Pasig City.

Barangay	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mandaluyong City											
Mauway	27065	27291	27517	27744	28423	29103	29614	30126	30638	31406	32174
Highway Hills	25941	26247	26554	26861	27782	28703	28835	28967	29100	29298	29497
Addition Hills	94029	94587	95146	95705	97381	99058	99602	100147	100691	101508	102325
Pasig City											
Manggahan	83749	84885	86021	87158	90567	93976	94514	95052	95591	96398	97206
Pinagbuhatan	136683	138382	140082	141781	146880	151979	154899	157820	160740	165121	169502
Rosario	59766	60005	60244	60484	61202	61920	61894	61868	61842	61803	61765

Table 4. Radiance Value of Light Pollution of Mandaluyong and Pasig City from 2013-2018.

		Light Pollution Data						
City	Barangay	VIIRS2018	VIIRS2017	VIIRS2016	VIIRS2015	VIIRS2014	VIIRS2013	Mean Value
Mandaluyong City	Mauway	42.56	38.8	44.51	32.38	29.9	30.88	32.5
	Highway Hills	64.49	64.91	66.8	58.64	44.73	48.12	57.94
	Addition Hills	37.83	40.47	41.39	41.15	37.68	39.44	39.66
Pasig City	Manggahan	27.09	23.3	21.91	20.94	19.15	20.12	22.08
	Pinagbuhatan	31.14	28.91	31.9	21.15	21.65	24.33	26.51
	Rosario	29.07	28	26.28	25	24.48	24.54	26.22

*****source: lightpolutionmap.com

The data for the most populated Barangay population in Mandaluyong and Pasig were from the www.citypopulation. The data shows a Five-year trend of population growth, however, there were no entries for 2005, 2010, and 2020. The values of 2005, 2010, and 2020 were interpolated and extrapolated using the five-year trend data entries from 1995 to 2015. Data entries for 2010, 2015, and 2020 were interpolated to get the yearly data from 2010-2020. The data were processed to show that there is consistency in the yearly increase of

population in the specified most populous barangays in both Mandaluyong and Pasig cities.

Table 4 shows the radiance values in the three most populated barangay in Mandaluyong city: Brgy Highway Hills with radiance mean value of 57.94, Brgy. Mauway with 32.50 and Brgy Addition Hills with 39.66 were significantly higher than the radiance values obtained in the most populated area in Pasig city: Brgy Pinagbuhatan with 26.51, Brgy Rosario with 26.22, and Brgy Manggahan with 22.08. According to Newport *et al.* (2014), the two major results of urban expansion that affect the wildlife are light and noise pollution. Profound effects on biodiversity brought by global population growth and associated urban development.

Table 5. Significance Value between Mandaluyong and Pasig City.

Group Statistics

	City	N	Mean	Std. Deviation	Std. Error Mean
Radiance Level	A	42	47.7010	13.86835	2.13993
	B	42	36.5074	15.68576	2.42037

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Radiance Level	Equal variances assumed	.062	.804	3.465	82
	Equal variances not assumed			3.465	80.787

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Radiance Level	Equal variances assumed	.001	11.19357	3.23071
	Equal variances not assumed	.001	11.19357	3.23071

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Radiance Level	Equal variances assumed	4.76666	17.62048
	Equal variances not assumed	4.76522	17.62193

Correlation between the population and number of buildings with the extent of light pollution in Mandaluyong and Pasig City

Table 5 shows that the Significant Value of radiance level of Mandaluyong and Pasig is 0.804 this implies that there is no significant difference between the two independent samples. The difference between the mean radiance value of Mandaluyong and Pasig city is statistically significant. Falchi (2018) coined the word ALAN which stands for Artificial Light at Night, he stated that the fact that ALAN operates against the natural characteristics of light/dark cycles,

it considered to be physical pollution. There should be a balance on the very evident adverse effects of ALAN on animals and on human health against the assumed (but yet to be proven) positive effects on safety and security. The urban, rural, and wild environment community will benefit by decreasing the pollution generated by lighting installations.

Table 6. Correlation table of Radiance Value, Building, and Population in Pasig City and Mandaluyong.

Mandaluyong City

Correlations

		Radiance Level	Buildings	Population
Radiance Level	Pearson Correlation	1	-.394	-.326
	Sig. (2-tailed)		.106	.149
	N	42	18	21
Buildings	Pearson Correlation	-.394	1	-.170
	Sig. (2-tailed)	.106		.499
	N	18	18	18
Population	Pearson Correlation	-.326	-.170	1
	Sig. (2-tailed)	.149	.499	
	N	21	18	21

Pasig City

Correlations

		Radiance Level	Buildings	Population
Radiance Level	Pearson Correlation	1	-.226	-.572**
	Sig. (2-tailed)		.313	.007
	N	42	22	21
Buildings	Pearson Correlation	-.226	1	.004
	Sig. (2-tailed)	.313		.986
	N	22	22	21
Population	Pearson Correlation	-.572**	.004	1
	Sig. (2-tailed)	.007	.986	
	N	21	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6 shows that the population and radiance value have a negative correlation with p (0.007) < 0.01, the alpha level reveals that there is a significant relationship between population and radiance value. There is a very high negative relationship of -.572 between population and radiance value. The negative relationship implies that the increase of population inversely proportional with the increase of radiance level radiance value. According to Pun *et al* (2014) to monitor in detail the conditions of light pollution in Hong Kong, the Hong Kong Night Sky Brightness Monitoring Network (NSN) was established. To continuously measure the variations of the NSB, monitoring stations were set up throughout the city to cover a wide range of urban and rural settings. From May 2010 to March 2013 over 4.6-million-night sky measurements were collected from 18 distinct locations. This huge data set is over two thousand times larger than the previous survey, served as the backbone for studies of the temporal and geographical variations of this environmental parameter and its correlation with various natural and artificial factors. Excluding data affected by the Moon, the average NSB in Hong Kong was 16.8 mag arcsec−2 or 82 times brighter than the dark site standard established by the International Astronomical Union (IAU). The effects of the city's artificial lighting sources on the night sky are conspicuous, urban night sky was on average 15 times brighter than that in a rural location.

The characteristics of observed light pollution in the Cities of Mandaluyong and Pasig from 2013-2018

It can be seen in Fig. 1 that the increase of population and establishments in Mandaluyong City is inversely proportional to the increase of radiance level radiance value. Bramley (2014) stated that like in many cities around the world, Hongkong is proud of its illuminated city. "The brighter the better," to some people "brighter means more prosperous. Hong Kong is nicknamed the Pearl of the Orient. To a lot of people take this actually as a badge of pride without rethinking what all this brightness means." Bramley (2014) reported that that one of the megacities trying to bring back its nighttime darkness is Los Angeles. LA opt-out uses apricot-colored street lights and has since undergone one of the world's largest LED streetlight replacement projects. Cities wanting to save on lighting costs are turning to LEDs which are proving to be a popular choice, LEDs are energy efficient and tend to be directional.

It can be seen on Fig. 2 that the increase of population and establishments in Pasig City is inversely proportional with the increase of radiance level radiance value. According to Kolláth (2010) established at the Zselic Landscape Protection Area in Hungary is one of the first 'International Dark-sky Parks' in Europe. Using 'Sky Quality Meters' and DSLR cameras, a special monitoring program has been carrying on to survey the quality of the night sky. The local villages have only a minimal effect on the quality of the sky was the main conclusion of measurements. The main source of obtrusive light is the city of Kaposvár, there are light-domes due to the neighboring cities only close to the horizon.

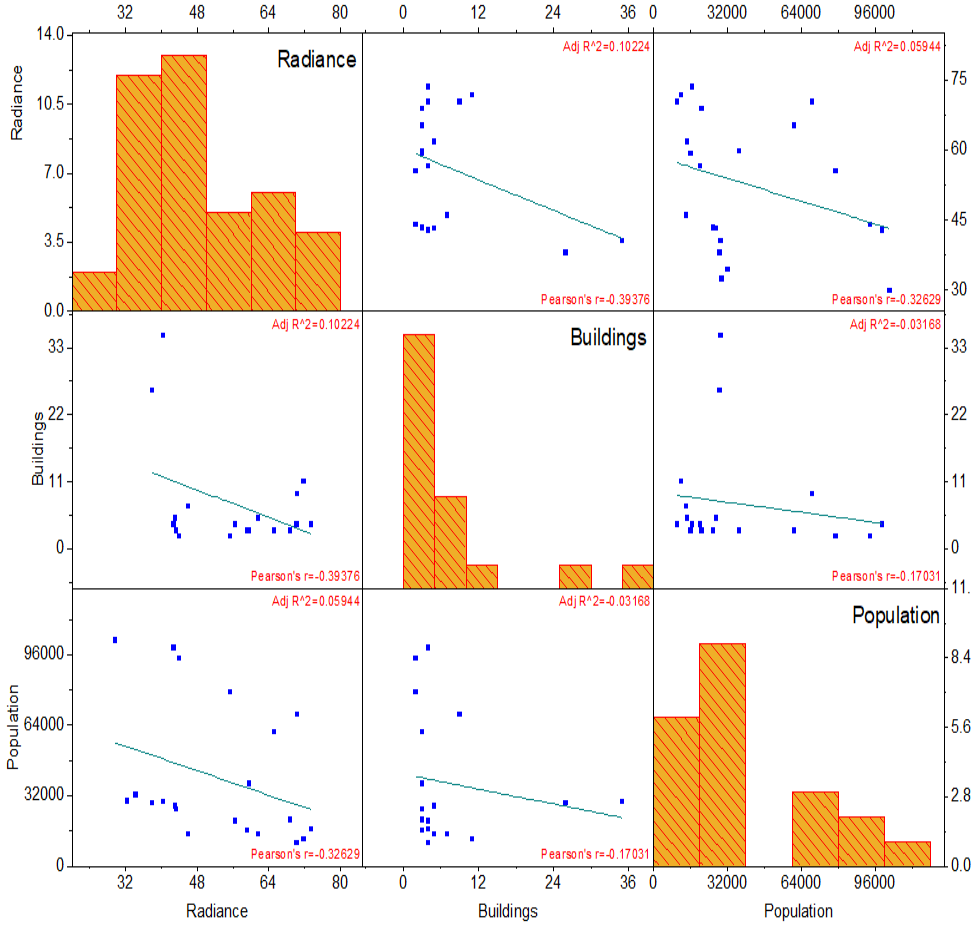

Fig. 1. Scatter Plot of Radiance Value, Buildings and population of Mandaluyong City.

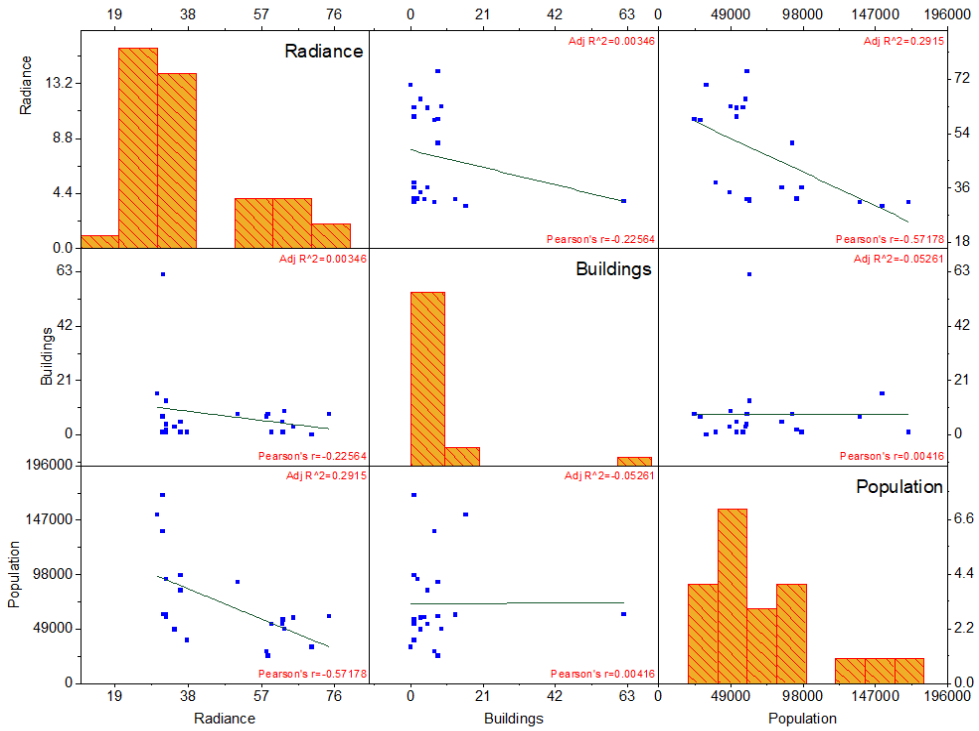

Fig. 2. Scatter Plot of Radiance Value, Buildings and population of Pasig City.

The anthropogenic component of zenith luminance of the night sky is obtained as the function of the distance from the city center of Kaposvár. These results of the study can help protect the nocturnal landscape of nature parks for the next generations by limiting the energy emitted uselessly to space.

The policies can be drawn according to the results of the study

1. The Local Government must regulate the usage of artificial lighting in:

1.1 Buildings;
1.2 Billboards;
1.3 Industrial areas;
1.4 Residential areas;
1.5 Streetlights and
1.6 Commercial areas

2. The Local Government must mandate the use of low glare lighting outdoor fixtures in their localities.
3. The local Government must replace conventional street lamps that have high-energy bulbs with efficient outdoor CFLs and LED floodlights.

Conclusion

The areas with numerous establishments located in Mandaluyong and Pasig shared a common characteristic, the proximity to major thoroughfares. Greenfield District and Megamall are located along EDSA while Metro walk is located along C5. These two major thoroughfares both have numerous street lights and peppered with big signages and LED billboards plus both of the roads have heavy traffic at night.

The residential setup in Mandaluyong is different from Pasig. All of the identified most populated areas in Mandaluyong have combined residential and commercial buildings while the most populated barangays in Pasig have low-rise houses and small-scale commercial centers.

The characteristics of observed light pollution in the Cities of Mandaluyong and Pasig from 2013-2018 due to the availability of data from the VIIRS. Both cities are highly urbanized and light-polluted. As the population in the two cities grows the housing demands also increase. Compact housing projects like high-rise condominiums and bliss were in demand since highly urbanized areas do not have enough space to develop subdivisions with single detached family houses. According to the results of this research, an efficient and strategical lighting system must be put in place; street lamps that floodlight upwards must be replaced. According to Elsahragty & Kim (2015), proper lighting system design is vital high-rise to light pollution. For efficient use of lighting energy, the location, mounting height, and aim of exterior luminaires need to be taken into consideration.

Signages' and LED billboards' light luminosity should be controlled and regulated. Policy on the correct and efficient usage of lighting instruments should be made and strictly be implemented.

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