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Topic: Assessment of light pollution in Clementi and the CBD

Slant: Geography

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Declaration

I declare that this assignment is my own work and does not involve plagiarism or collusion. The sources of other people's work have been appropriately referenced, failing which I am willing to accept the necessary disciplinary action(s) to be taken against me.

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Date of Submission:

Chapter 1: Introductory Chapter

1.1 Background

Light pollution is defined to be the “brightening of the night sky caused by street lights and other man-made sources, which has a disruptive effect on natural cycles and inhibits the observation of stars and planets.” according to the Oxford Dictionary. It has been observed to be a serious and ongoing problem in Singapore which has not been widely addressed until a 2016 study by the Light Pollution Science and Technology Institute placed Singapore as the most polluted nation in the world. Despite the seriousness of the problem, not much action is observed to be taken to curb this issue which will be further elaborated in Chapter 2.1.

1.2 Rationale

The change from sodium vapour streetlights to light-emitting diode (LED) streetlights started from 2010 in Singapore caused the increase in light intensity per streetlight. LED lights have been proven and widely accepted that it is the most energy efficient, however, there are certain trade-offs such as large amounts of light given out to the environment, which can be one of the main causes of light pollution in Singapore. On the other hand, while the sodium vapour light is less energy efficient, the light intensity is more comfortable to the eye and it does not emit too much light to the surroundings. Furthermore, with the structure of the buildings in Singapore, ceiling and table lights will, in some instances, affect residents in the opposite buildings, which can cause inconveniences. Studies have also shown that long term exposure to bright lights at night can affect sleep cycle and cause various health problems, thus rendering light

pollution as a serious problem. This paper will identify the causes of light pollution in Singapore through measurements of light intensity and investigate the impacts on residents through surveys or interviews.

1.3 Research Questions

- a) Is light pollution an issue in Singapore?
- b) Does Singapore really need such bright lights?
- c) What suitable changes could Singapore make to streetlights so that we can keep the energy efficient lights but cut down on light pollution?
- d) How has light pollution affected residents living close to main roads?

1.4 Thesis Statement

LED Streetlights are the main source of light pollution in Singapore as compared to the older sodium powered lights, and such light pollution would bring about discomfort to residents living close to the main roads.

1.5 Scope of Research / Delimitation(s)

This research is limited to complementing two residential areas in Singapore, mainly Clementi and Orchard Road. The results collected will then be used to contrast with a busy area in Singapore. Sources of light pollution can include car lights, household ceiling lights, but mainly the comparison of the impacts of LED lights and sodium vapour lamps. This paper also looks at different opinions of residents living in these areas so that response collected can facilitate the research.

1.6 Significance of Research / Usefulness

This study aims to shed light on the impact and causes of light pollution and through that hope to improve urban planning in Singapore for the future.

1.7 Limitations

This paper might be limited in ensuring the number of light sources measured in one area stays the same the other. The readings taken in different places will vary due to other sources of light present. However, the readings will be carefully analyzed, and such inaccuracies will be taken into account. Furthermore, due to the Covid-19 situation, it would not be possible to interview residents face-to-face, thus the responses of surveys may be limited to a few options. The impacts of light pollution cannot be measured objectively as the amount of light which causes one to feel discomfort may vary from person to person. The results will be subjective, but it will still be an accurate depiction of the situation in that area.

Chapter 2: Literature Review

2.1 Background

Light pollution is a widely accepted term for adverse effects of artificial light on nature and humans (Longcore and Rich 2004, Navara and Nelson 2007). Light pollution has been an effect of the increased usage in artificial lighting and, when states and countries are moving towards more energy efficient artificial lighting, there might possibly be a wider loss of dark nightscape as a consequence. Artificial light consumes about 19% of total electricity and accounts for greenhouse gas emissions of 1900 Mt of CO₂ per year (OECD/IEA 2006). It comes as no surprise that states and countries are making policies and moving towards a more energy efficient form of artificial lighting. With less energy consumption comes reduced cost, which will reduce costs and could generate steep increases in the overall use of lighting and may stimulate innovative additional uses for lighting (Herring and Roy 2007). Light pollution has not been as widely researched as other forms of pollution such as air, noise or water pollution. The argument presented in *The Dark Side of Light: A Transdisciplinary Research Agenda for Light Pollution Policy* (Frannz et al., 2010) suggests that “any attempts to reduce light pollution run up against positive connotations of lighting which are deeply ingrained in modern societies.” Light has always been a symbol of enlightenment, modernity, urbanity, and security (Jakle 2001) and the authors suggest that policies to reduce the amount of light pollution has to take into the significant amount of advantages for the use of artificial lightings, while at the same time addressing the negative side effects. These studies have addressed many issues regarding the current policies in reducing light pollution and have provided useful insight into how this problem may be addressed in Singapore.

2.2 Implications of light pollution

Studies on light pollution all suggest that light pollution can cause health and safety related issues. Research done by John Gelder has shown that elderly take 2 to 5 minutes for their eyes to adjust to low level light after being exposed to high level lights. One example is when one leaves a brightly lit petrol station, he or she would be unable to clearly distinguish cars on the roads, compromising their safety. Reiter et al. 2011 also pointed out in his research on the effect of light pollution on our circadian system, that the increased usage of light at night has “altered the natural light-dark cycle contrast”. This means that this could lead to chronodisruption, where sleep hours of children have been observed to be decreased by 1.2 hours. Although light pollution was not explicitly mentioned as a huge contributing factor to chronodisruption, he suggested that since darkness at night is desirable, reducing light pollution will have a significant impact on improving human health. Gelder proposed to follow the Australian Standard 4282-1997 to design outdoor lighting. This Standard states the acceptable upward light waste, the amount of light let into a window and intensity of light. While it may be common belief that bright lights will dictate lower crime rates, research done by Luz Claudio shows otherwise. He pointed out that on 25 November 2008 the *Colchester Gazette* reported that towns in Essex County, United Kingdom has seen a decrease in crime during a pilot project where essential streetlights were turned off after midnight. The results obtained was shocking as it showed that the number of recorded offences fell by 14% when the streetlights were turned off while offences fell by 12% overall. In fact, he believes that with brighter lights, offenders would be able to see victims clearer, increasing the chances of crime. While the impact of light pollution on the environment is widely agreed to be significant, this paper will not be looking into such implications but is rather focused on that of human health and safety.

2.3 Case studies

While the causes of light pollution in a specific area has not been clearly identified in the studies reviewed, much research done on light pollution have concluded that this type of pollution is the easiest to remove from the environment. The problem of light pollution has been studied in Bangor, Maine, where restrictions were put in place to reduce light pollution, according to Rebecca Berg. These restrictions include limiting the height of streetlights to 24 feet and require full horizontal shielding luminaries. Causes of light pollution have been identified in Plano, Texas in the same study, showing that lights from football fields and shopping malls are of concern to citizens. These causes may be different from country to country, but what contributes to light pollution is having excess light at the wrong time. One method to model nighttime light pollution is through producing an areal map of zenithal sky brightness over a certain area. This method was used to model light pollution in the USA and was conducted by many researchers, one of which is Garstang (1986). This method takes into account the population of a city and is assumed to be related linearly to the population and the inverse 2.5 power of the distance. (Steve and Dan, 2001). While this method may not be applicable in this research in Singapore, as population spread in Singapore is almost neglectable, this methodology is one to refer to when taking readings. Much research has also been done on the astronomical effect of light pollution and all results point to bright city lights causing light pollution. Another method used to measure sky brightness in 1975 was used by Osterbrock et al., 1976, which takes the sky spectrum and subtract from the galaxy plus sky spectrum to quantify the effect of light pollution on the night sky. Although this research was done in 1975 at Mount Hamilton, where LED lights were not common at that time, the results clearly showed that the problem of light pollution has worsened over the time and leads one to conclude that it will worsen in the future.

3. Methodology

This paper focuses on measuring the intensity of light in different areas of Singapore, namely Clementi and the CBD. To measure the light intensity, a lux meter will be used which measures the amount of light cast on a unit area. What it will measure will include, but not limited to: streetlights, car lights and traffic lights. The data collected will be analysed, and paired with surveys with residents in those areas to determine the intensity of the problem in that area. The measurements will be taken at 8pm in the different areas to ensure the consistency of the results. The distance and intensity of the light source can be derived from a formula as the intensity per unit area varies in inverse proportion to the square of the distance. The measurements of a light source will be taken from a lux meter, with readings taken at shoulder level (1.4m off the ground) as it would be dangerous to take readings at ground level. Surveys will also be conducted with residents of the area to determine the impact of light pollution. The survey questions can be seen below.

4. Discussion and analysis

Survey results

Survey results in Clementi show that light pollution has not affected the majority of residents there. 30% of respondents live above the 10th floor and claim they are not affected by the bright lights on the street. However, one respondent living on the 15th floor pointed out that corridor lights are of a concern to him, as which cause him to feel “uncomfortable when moving around these areas”. As he had pointed out, lights along corridors are bright LED lights which are close to one’s room. Another respondent who lives on the 3rd floor felt that traffic lights were too bright and had caused him sleeping difficulties. From the table below, it can be seen that most residents living on lower levels do not feel that bright lights would affect them. However, this does not take into account the direction they are facing. On the other hand, all of the respondents who live above the 5th floor do not feel affected by streetlights. This survey goes to show that the height of residence would affect the amount of light reaching one’s homes from streetlights, which would be further discussed in the next section.

What is your age group?	Which level is your apartment on?	Do you feel that the lights in the neighborhood are too bright?	If so, please answer questions 3 to 5. What would be the main contributors to the brightness of the area?	How might this affect your daily life? (Sleep cycle, visibility. or maybe not at all etc.)	Would you consider the amount of light entering your home / room to be excessive?	Do you think that bright lights are necessary in Singapore?
14 - 20	15	Yes	Corridor lights	Uncomfortable feeling	No	No

				when moving around these areas		
14 - 20	35	No				Yes
14 - 20	12	No				Yes
14 - 20	1	No		Visibility due to poor lighting	No	No
14 - 20	9	No				Yes
14 - 20	1	No		Visibility due to poor lighting	No	No
40 - 60	1	No				Yes
40 - 60	1	No	Streetlights	Na	No	Yes
14 - 20	3	Yes	Traffic Lights	Hard to sleep	Yes	No
14 - 20	9	No				Yes
14 - 20	12	No				Yes
14 - 20	2	No				Yes

Intensity of lighting in Clementi

Light intensity taken in Clementi are of sodium powered streetlights which are 6m tall. The readings were taken at Faber Walk where there are 69 streetlights which receive

very little interference from other sources of light. Light intensity was also measured at a traffic junction in between Jalan Lempeng and Commonwealth Avenue West. The results obtained are shown in Fig. 1.0.

	Light intensity / lux	Amount of light reaching the ground / lux (calculated by the inverse square function)
Faber Walk Streetlight 1	29.69	17.50
Faber Walk Streetlight 2	37.72	22.20
Faber Walk Streetlight 3	29.10	17.10
Faber Walk Streetlight 4	34.74	20.40
Faber Walk Streetlight 5	34.17	20.10
Faber Walk Streetlight 6	25.60	15.00
Faber Walk Streetlight 7	30.57	18.00

Faber Walk Streetlight 8	38.29	22.50
Faber Walk Streetlight 9	33.17	19.50
Faber Walk Streetlight 10	29.42	17.30
Faber Walk Streetlight 11	38.46	22.60
Traffic Junction	31.0 - 52.9	-

Fig 1.0

The table shows an inconsistency in light intensity from the streetlights. Since this batch of streetlights is from 2012, this result could be due to the different speeds at which these lights wear out, thus decreasing in intensity in different speeds. From Fig 2.0, we can see the junction from which the last reading was taken.



Fig 2.0

This is not a huge junction, yet the reading had such great fluctuations from 31 lux to as high as 52.9 lux. This is caused by the number of cars along the road which uses bright LED lights. This could also be caused by the greater light intensity of the streetlights used to illuminate the streets. However, light intensity of these lights would not be able to be taken as there are just too many other sources of lights which would affect the results. Throughout the walk in Clementi, I have also noticed that lights from private properties are especially bright, one example would be Nan Hua Primary School. There is a long stretch of LED lamps placed about 6 to 10 meters apart, around the boundaries of the school. These lights are unnecessary as there will not be anybody in the school at 8pm. One suggestion would be to turn on only 50% of the lights so that total light intensity would be cut down. When I was 1m above the streetlights, there was very little light leaked upwards, to as little as 0.2 lux. However, since light can be reflected off surfaces, this would cause a greater amount of light emitted towards the sky, causing a glow in the sky. As roads tend to be more reflective to help improve visibility of drivers, much of the light that reaches the ground would be reflected upwards, towards buildings and homes. However, this finding is disproved by the survey results gathered as the majority of the residents do not feel affected by the lights on the roads.

Intensity of lighting in the city

Light intensity in the city was taken from LED powered streetlights which were 10m high. They were taken along Raffles Boulevard. The area in which the readings were taken can be seen in Fig 3.0 and Fig 3.1. The results of the measurements can be seen in Fig 4.0.

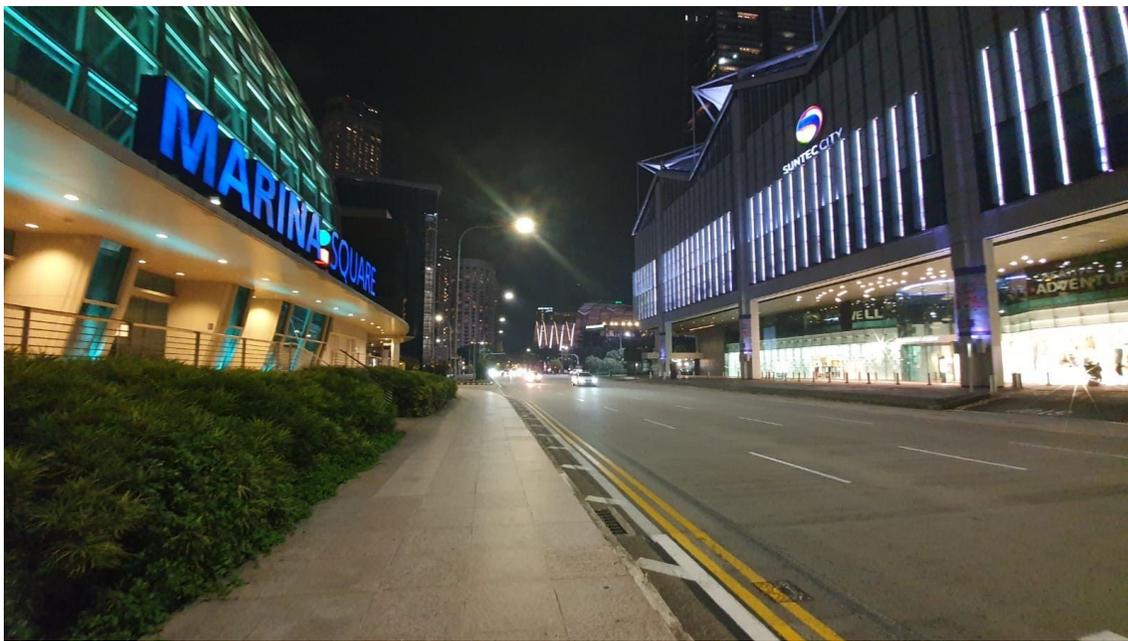


Fig 3.0 (top) and Fig 3.1 (bottom)

From these two pictures, we can see that this stretch of road is brightly lit by LED streetlights and the malls around it (Suntec City and Marina Square) also contributes to the overall brightness.

Streetlights	Light intensity at shoulder level / lux	Light intensity that reaches the ground / lux
Raffles Blvd Streetlight 1	45.7	33.8
Raffles Blvd Streetlight 2	46.9	34.7
Raffles Blvd Streetlight 3	45.3	33.5
Raffles Blvd Streetlight 4 (Close to Marina Square)	57.6	42.6
Raffles Blvd Streetlight 5	44.1	32.6
Raffles Blvd Streetlight 6	47.2	34.9
Raffles Blvd Streetlight 7	40.4	29.9
Raffles Blvd Streetlight 8	41.6	30.8
Raffles Blvd	45.8	33.9

Streetlight 9		
St Andrew's Road Streetlight 10	44.6	33.0
St Andrew's Road Streetlight 11	51.4	38.0

Fig 4.0

The fluctuations in intensity of LED lights remained small and some of the outliers were taken close to Marina Square. Walking past Marina Square, the reading on the lux metre shot up to 111.3 lux, which is more than 2 times the intensity of the LED lights. Although visually LED lights seem significantly brighter than that coming from the shopping mall, the data shows otherwise. This result comes as surprising and it goes to show that lights from malls are a huge contributor to light emitted to the surroundings, whether we know it or not. While walking around the Central Business District, I noticed that the main source of light did not come from the office buildings, but rather from the bright street lights. Since most people do not work at night, office lights are turned off, leaving only the lobby lights on, which does not contribute greatly to light pollution. While streetlights may have a huge impact on the overall brightness of the area, the sheer amount of cars in the area also greatly contributes to light pollution. Car lights are designed such that light is reflected in all directions as it exits the bulb. This increases the spread of a car light and adds to the light intensity in the area. Furthermore, each car contains at least 4 different light bulbs, and each of them reflects light in all directions, this further magnifies the amount of light produced.

Comparison of light intensity in both areas

When looking at results in both areas, light intensity in the CBD is definitely greater than that in Clementi. Lights in Clementi are sodium powered while lights in the CBD are

LED, and the number of cars in CBD is clearly greater than that in Clementi. This could be one of the main contributors to light pollution. When looking at pictures of aerial view of Singapore at night, a large amount of light can be seen to be emitted from the top of office buildings. These are lights from logos of companies which could not be measured. However, I believe that since such lights are closer to the sky, it would definitely contribute to sky glow in Singapore. Another thing that can be seen from aerial footage is that streetlights from CBD are reflected from the ground into the sky. This is due to the great density of street lighting in the area which would increase the total amount of light hitting the ground. As seen in Fig 4.0, the light intensity from streetlights in the CBD is significantly greater than that in Clementi. Furthermore, the height of the streetlights are different, with the ones in the CBD being higher, yet the light intensity is still significantly greater. This shows that the amount of spread is way greater and that more light will be emitted to the surroundings. Residents in Clementi do not feel that lights in their neighbourhood are too bright, this leads me to think that maybe one would have adapted to the brightness of the surroundings after years of living there. Another problem identified in residential areas is that the corridor lights are too bright. These lights stay on throughout the night and with the closely packed buildings in Singapore, lights from different buildings collectively lights up the sky. One possible reason as to why Singapore has a huge problem of light pollution is that Singapore is a densely populated city. With closely packed buildings and every road lit up by bright LED lights, this makes Singapore one huge light bulb. Just by collecting data from one small area in Singapore would not be enough to determine the intensity of the problem, but rather one should collect data in Singapore as a whole so that one can see the big picture. However, this paper shows that there is indeed a difference in light intensity between the CBD and residential areas in Singapore. Whether or not this would affect one's daily life is purely subjective and perhaps we might have already gotten used to the lighting conditions in Singapore to the extent that we are not used to the darkness we see in other countries. Through the survey, it can also be seen that people feel the need for bright lights, perhaps due to the fact that such bright lights have brought about more

convenience than inconvenience to their lives. Impact of light pollution cannot be easily quantified, thus many do not realise the extent of the problem and that surveys might not be accurate due to different people's perception of "excessive light".

Suggestions

Through data collection in two different areas in Singapore, I can conclude that there are unnecessary lights in Singapore. This may or may not affect residents in the area but it definitely contributes to light pollution. Thus some suggestions would be:

1. Control lighting in private properties

This means that office buildings, schools, etc, should be required to lower the brightness of lights in the lobby or around the compound. This not only prevents excessive light at night and also cuts down on energy usage.

2. Lower corridor lighting at around midnight

Corridor lighting can cause a huge impact to residents living by the corridor as seen through the survey done. Since these lights are the closest to one's homes, it will be the most important lighting to control.

Overall, light intensity can be controlled in Singapore, but the problem of light pollution must be brought to the attention of policy makers.

3. Consider varying streetlight intensity in less populated areas

There would not need to be such bright lights in areas where there are less people. This change would be the first step towards controlling light pollution in Singapore.

5. Conclusion

This paper has successfully compared the different light intensities in the CBD and Clementi and can conclude that light intensity in the CBD is clearly higher than that in Clementi. Various factors contributing to the light intensity have been identified to be mainly streetlights and mall lights; the former of which did not seem to have an impact on residents staying in Clementi. The problem of light pollution has been clearly identified as the overall light intensity has contributed to a glow in the sky. The fact that lights from sources apart from streetlights have caused inconvenience and discomfort shows that this problem of excessive lighting at night is clearly an issue that needs to be addressed. At the moment, residents feel that bright lights are necessary in Singapore and thus policies should gradually decrease our reliance on bright lights and get used to the normal lighting intensity. To conclude, the results gathered were reflective of the intensity of light pollution in Singapore. However, there is still much more extensive research to be done on this topic and policies can only be implemented with cooperation of residents.

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