

Urban Light Pollution: A Case Study of Hong Kong by Chit Yu Stephanie Lau

Independent Research Project 2016



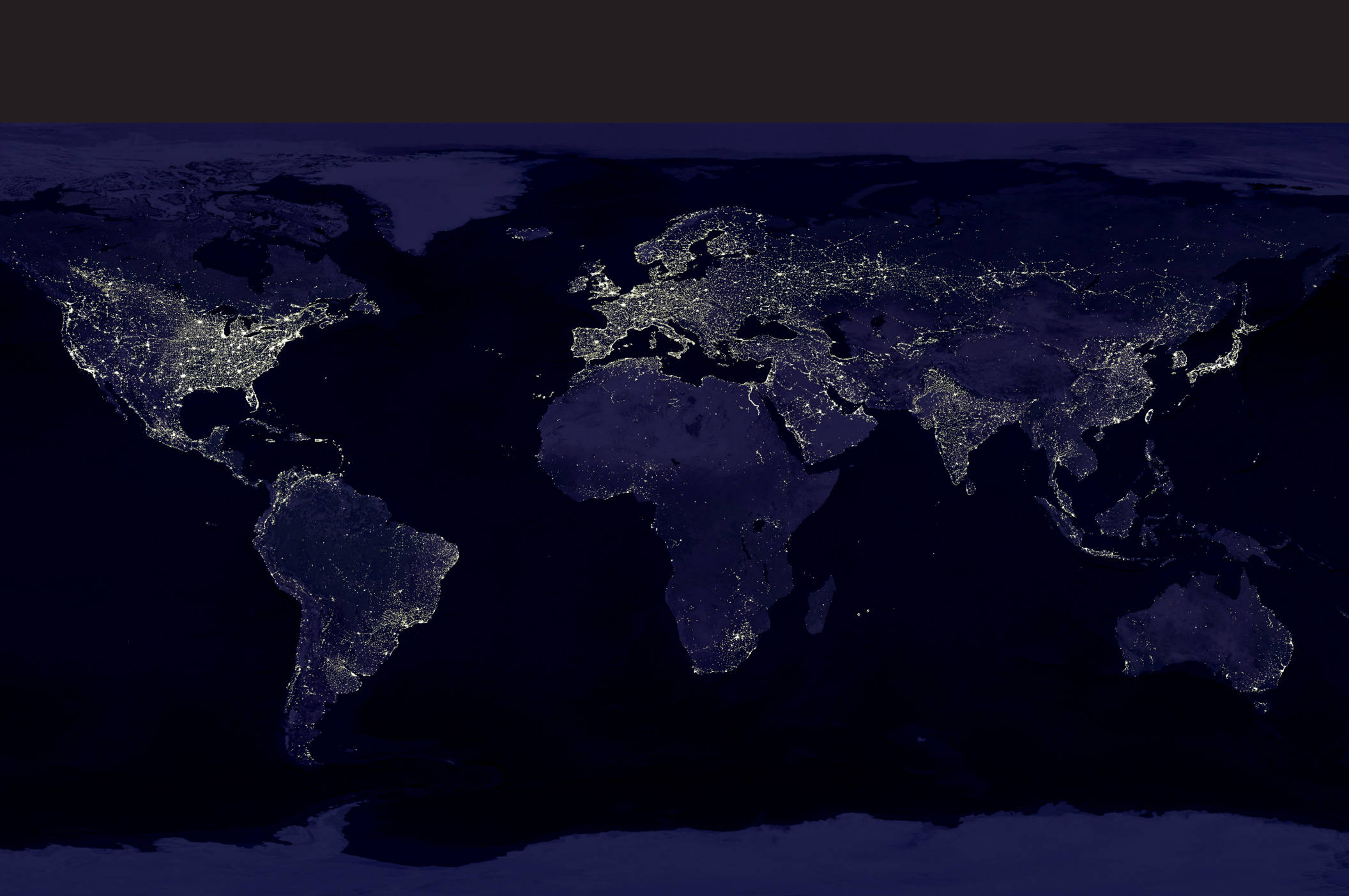


figure 1: *Earth At Night*, NASA

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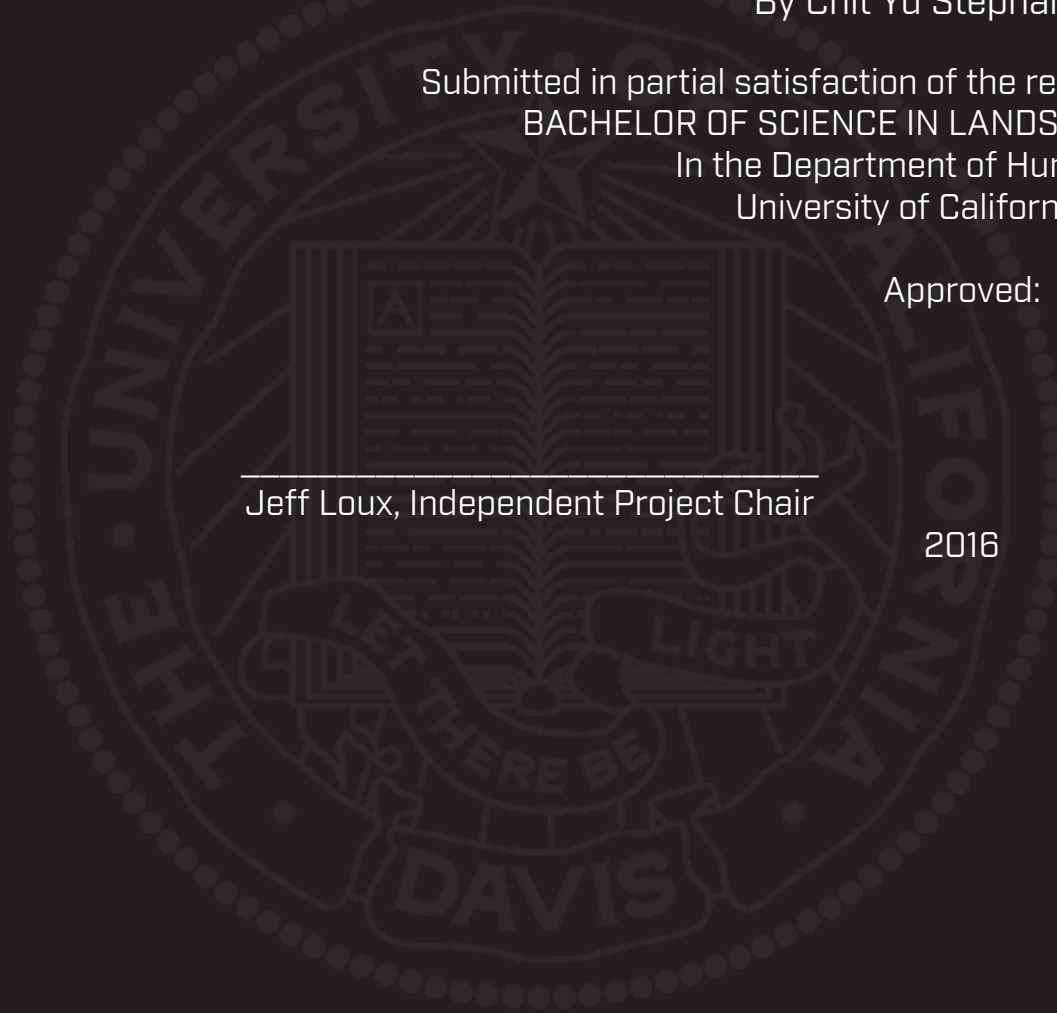
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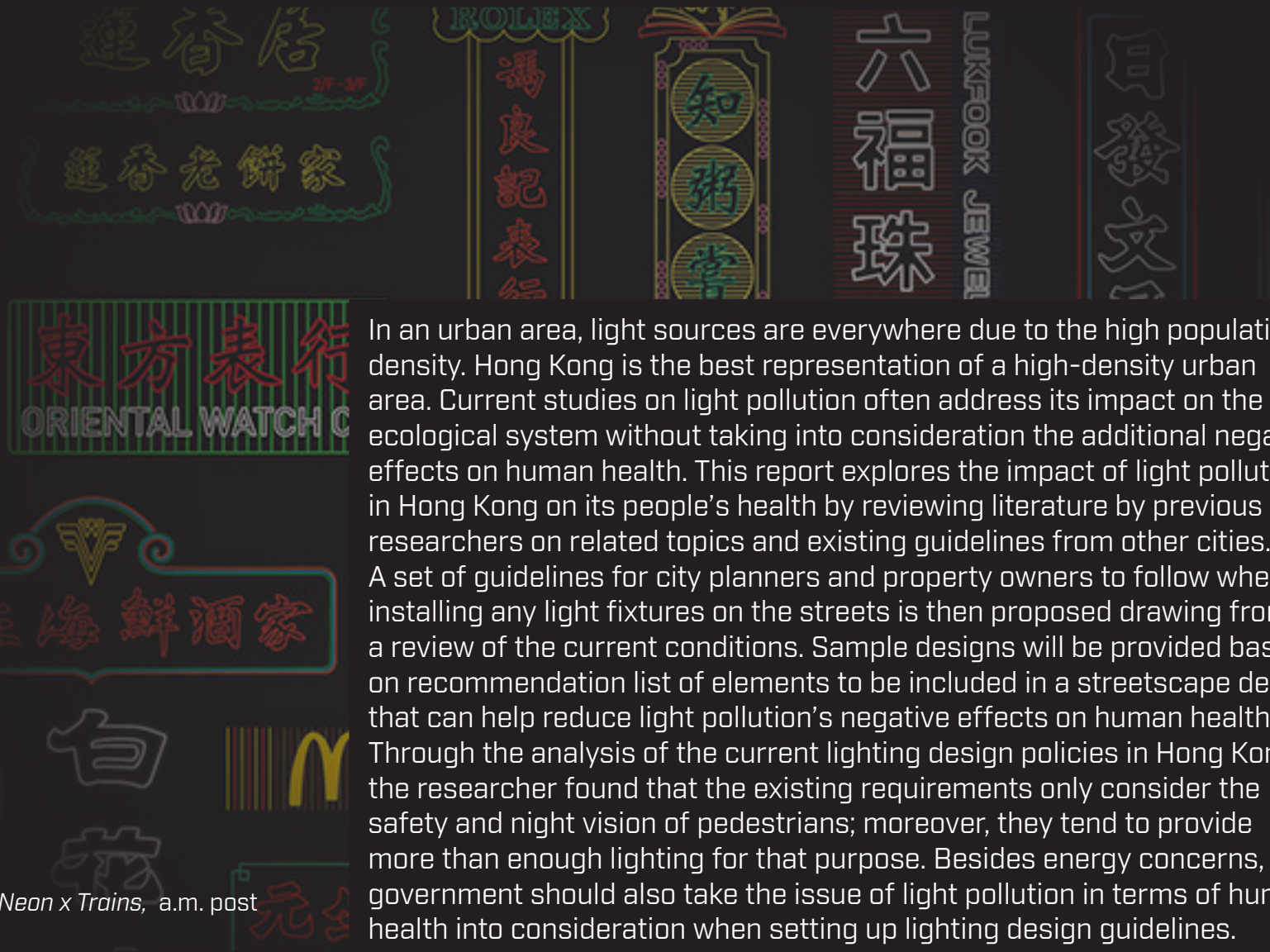
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abstract



In an urban area, light sources are everywhere due to the high population density. Hong Kong is the best representation of a high-density urban area. Current studies on light pollution often address its impact on the ecological system without taking into consideration the additional negative effects on human health. This report explores the impact of light pollution in Hong Kong on its people's health by reviewing literature by previous researchers on related topics and existing guidelines from other cities. A set of guidelines for city planners and property owners to follow when installing any light fixtures on the streets is then proposed drawing from a review of the current conditions. Sample designs will be provided based on recommendation list of elements to be included in a streetscape design that can help reduce light pollution's negative effects on human health. Through the analysis of the current lighting design policies in Hong Kong, the researcher found that the existing requirements only consider the safety and night vision of pedestrians; moreover, they tend to provide more than enough lighting for that purpose. Besides energy concerns, the government should also take the issue of light pollution in terms of human health into consideration when setting up lighting design guidelines.

figure 2: *Neon x Trains*, a.m. post

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figure 4: *Hong Kong Night View*, Google Image

introduction

As urban areas rapidly grow, air pollution from factories, noise pollution from vehicles, and water pollution from stormwater runoff also increase. Increasingly, light pollution can be added to the list of environmental problems. Light pollution is defined by Haim and Portnov (2013) as the following:

1. environmental pollution consisting of the excess of harmful or annoying light;
2. wasted light from city and outdoor lights that makes it hard to see the stars at night;
and
3. misdirected, unshielded, excessive and/or unnecessary night lighting aimed upwards or sideways, scattering light across the atmosphere, brightening the night sky, while diminishing the view of it. (p. 62)

When discussing environmental problems of urbanization, Hong Kong epitomizes dense urban challenges. According to the website of the Hong Kong government, Hong Kong had a population density of 6,650 people per square kilometer in 2014, and is the densest city in the world (2015). As a comparison, the densest city in the United States, which is Los Angeles, CA, has a population density of 1,046 person per square kilometer (World Atlas, 2015). The result of being the densest city in the world is that land has to be used efficiently. Constructing tall buildings is one solution to the high demand of residential apartments. Buildings often reserve their ground floors for commercial use,

introduction- con't

and only the upper floors are for residential use. A second way to ensure well-use of every inch of the land is to plan everything in the city close to one another; this density leads Hong Kong to be called a Concrete Jungle. Due to this reason, Hong Kong has very narrow streets. Narrow streets plus high daily traffic of both pedestrians, as walking is one of the main way to commute from destination to destinations in Hong Kong, and vehicles are basically putting a large number of people into a trap that is full of pollutants.

There is much more light pollution in Hong Kong compared to any other city in the world. First, any pollutants that are produced within the city are easily trapped due to the city's structure. Second, light sources are everywhere on any typical street in Hong Kong, from ongoing traffic to advertisement boards hanging overhead. Light pollution does not only affect ecological habitats, but also people, both on the streets and at their home, who are directly exposed to these excessive illumination.

In this paper, effects of light pollution are explored. A list of lighting design guidelines will be created by asking the question, "How can streetscape design reduce health issues caused by light pollution from the streets?" Sample designs will be provided to give a better understanding of how the elements can integrate and corporate with one another to reduce negative effects of light pollution.



problem statement

In Hong Kong, a high-density urban area, streets are very narrow, and the city is being compacted by high-rise buildings. Due to the built environment of Hong Kong, environmental pollution remains in the city. Light pollution is one of them. According to Peter Shadbolt, a reporter from CNN, light pollution in Hong Kong is the worst in the world, because it “is as much as 1,000 times brighter than international norms” (2013).

Light pollution affects lives in many different ways. Recent research on light pollution mainly focuses on exploring how it is affecting the ecological system (Brüning, Hölker, Franke, Kleiner, & Kloas, 2016; Raap, Pinxten, & Eens, 2015); however, its effects on human mental health is rarely being addressed. Mental health, especially mental stress, is an issue a lot of people living in an urban area are facing nowadays, and is mainly due to busy working schedules. Environment is another important aspect that leads to mental stress. According to previous studies, urban environments often make people feel stressed and cause higher blood pressure compared to natural green space (Coss, 1996; Grahn & Stigsdotter, 2003). In Hong Kong, when people are exposed to artificial lights while walking on the streets and staying at home, the constant illumination keeps their brain active and can affect their sleeping quality (International Dark Sky Association, 2014). Bad sleeping quality can often exhaust brains and affect decision making and memory, which will lead to poor working performances and potential safety hazards.

problem statement- con't

There are many different light sources in Hong Kong at night time, such as ongoing traffic. Headlights from vehicles shine directly on pedestrians on the streets. Additionally, businesses on ground level of buildings use bright indoor lights to attract customers, which also create a large amount of wasted energy. Pedestrians on the streets are highly exposed to these ground level lightings, and the exposure will definitely affect their mental health, which will lead to their brains being continuously stimulated, and hence, they will not be able to relax their minds at night.

Residents living close to the busiest streets are exposed to distractions and pollutants easily, even when they are at home. Apartment units are highly illuminated by advertisement boards and spotlights which are hanging right outside of the windows. These distractions will affect the indoor homing experience and impede the residents from relaxing. Nelson, an interviewee on a TV program created by TV station TVB, said that as a college student, neon lights from advertisement boards which were hanging outside of his apartment illuminated his home directly (Light Pollution, 2005). "Flash lights were especially distracting when they were right outside of one's windows," said Nelson (Light Pollution, 2005).

Nelson, during the interview, said that the lights from outside distracted him from doing



figure 6: *The Bright Lights of Hong Kong*, CNN

problem statement- con't

his homework, and this did not improve even when he had his thick curtains on (Light Pollution, 2005). The Lee family, another interviewee from the same TV show, said that the neon lights could not be blocked by the thick curtains, and they could see the color red while closing their eyes (i.e. light going through retina); Mr. Lee's grade-school son claimed that he could not sleep well at night because of those lights from outside (Light Pollution, 2005). These interviews showcase the impact of street lights on relaxation. The lights distract people directly from their work and sleeping quality.

Light pollution affects sleeping quality by adding stress to the human brain and preventing a person from fully relaxing. Lambert and her colleagues believe that light with a short wavelength, which is a commonly being used in any light sources in a city, increases depression rate of people living in the city comparing to those who lives in the suburb, because it "disrupts brain circadian rhythms leading to impaired affective responses has not been ruled out" (2015). The negative effect of artificial light on human health is recently recognized by the American Medical Association (AMA) as an environmental pollution that affects human sleeping quality, and hence, sleeping cycle (Haim & Portnov, 2013). Being exposed to excessive artificial lights is believed to increase the chance of mood-related disorders, not only depression. According to Lambert et. al (2015), studies have shown that urbanization and mood disorder

problem statement- con't

rates are highly correlated, yet no one has discovered the direct reason to explain the relationship. One of the evidence that researchers have found was the Old Order Amish living in the states, who did not exposed to as much artificial lights, has reported to have around 1% of major depression rate, comparing to people who lived in the cities, 15% of the population is suffering from major depression; besides depression, the Amish has also been found to have a much lower chance than the typical population on having cancer, obesity, and other disorders that are believed to be connected to exposure of artificial light at night (LAN). Night shift workers are also found to have a higher risk of mood disorders because of being exposed to LAN which disrupts biological cycle. An example of that is emerging nurses working at a night shift for three months reported feeling helpless, anxious, and having low social support/interaction (Lambert et. al, 2015). Although, in theses studies, the relationship between LAN and mood seems not to be clearly explained and proven, LAN and sleeping quality are definitely correlated. Light can effectively wakes one up in the morning, because light goes through retinas and stimulates brains, and hence, activate one's organisms. Since the invention of light bulbs in the 1880s, human has been sleeping for less hours than in the past; before having LAN, human was reported to be sleeping for nine hours a day, but nowadays, people are sleeping for an average of seven and a half hour a day (Mizon, 2012). "Urban light pollution, night shift work, transmeridian travel, televisions and computers have



problem statement- con't

dramatically altered the timing of light used to entrain biological rhythms” (Bedrosian & Nelson, 2013). Disturbed biological rhythms are found to be playing a major role in affecting human mood and impair brains, affecting learning abilities and memories, “suppress melatonin secretion and other circadian responses in humans,” and creates negative impacts on “health consequences, including increased negative affect and feelings of helplessness” (Bedrosian & Nelson, 2013).

Despite its negative effects to human, when addressing the problem, one must keep in mind that lights, such as those from neon advertisement boards, are part of the culture of Hong Kong. As Nelson, the design student mentioned before, said that although those lights from the street were affecting his sleep and work, they also inspired him with ideas for his design projects (Light Pollution, 2005). It is also important to note that, the excessive lightings are from street lights that are intended to serve as a safety purpose of pedestrians and vehicles, and the signage with lights are an essential part of Hong Kong’s economic development.



purpose statement and research question

When designing and planning a city's streets, one should put any possible types of pollutions into concern. It is important for the society to realize the effect of light pollution to people's health, and for designers and planners to know how a design can worsen or improve an environmental issue. Lights are important in a city for safety reason; a study has shown how light was important in order to make people feel safe during the night (Stamps, 2007). But when there are more than enough lights, or when light sources are being put at wrong locations, there will be a waste of energy and will affect human's life.

Bad designs cause illnesses; on the other hand, good designs heal illnesses. By redesigning the environment with light pollution in mind, one can change the streets, which are almost the only open area Hong Kong people have access to, into a healthy landscape that can help improving its users' health and release stress.

The research question of this study is: How can streetscape design reduce health issues caused by light pollution from the streets? The main sources of light pollution, as well as in what ways they are affecting human's daily life is explored. A recommendation list of design guidelines that can effectively help eliminating those impacts under an urban setting will be created after the research. The end product will help with policy making, future planning, and street renovation/design under an urban setting, especially for Hong Kong. This report focuses on the negative impact of light pollution on human health, a subject which has not been largely addressed.





figure 10: Nathan Road, Google Images

research design, methods, and data collection

Due to the location of the site, this research is highly relied on existing information and previous research done by other researchers. The design process is divided into six steps.

First, the relationship of light pollution and mental stress is analyzed through a thorough literature review. Existing lighting design recommendations and requirements of Hong Kong is then reviewed. Through the revision of existing guidelines, problems of the current guidelines were identified. Lighting design recommendation from the Dark Sky Society and policies from mainland China were being used as a reference and example when creating new lighting guidelines for Hong Kong. After reading and analyzing all of the readings, new lighting design guidelines were modified according to the special condition of Hong Kong.

The researcher found that the existing Hong Kong lighting design guidelines only consider the safety of the structure itself, night vision of pedestrians and vehicles, and energy saving, and does not properly address the issue of light pollution in terms of

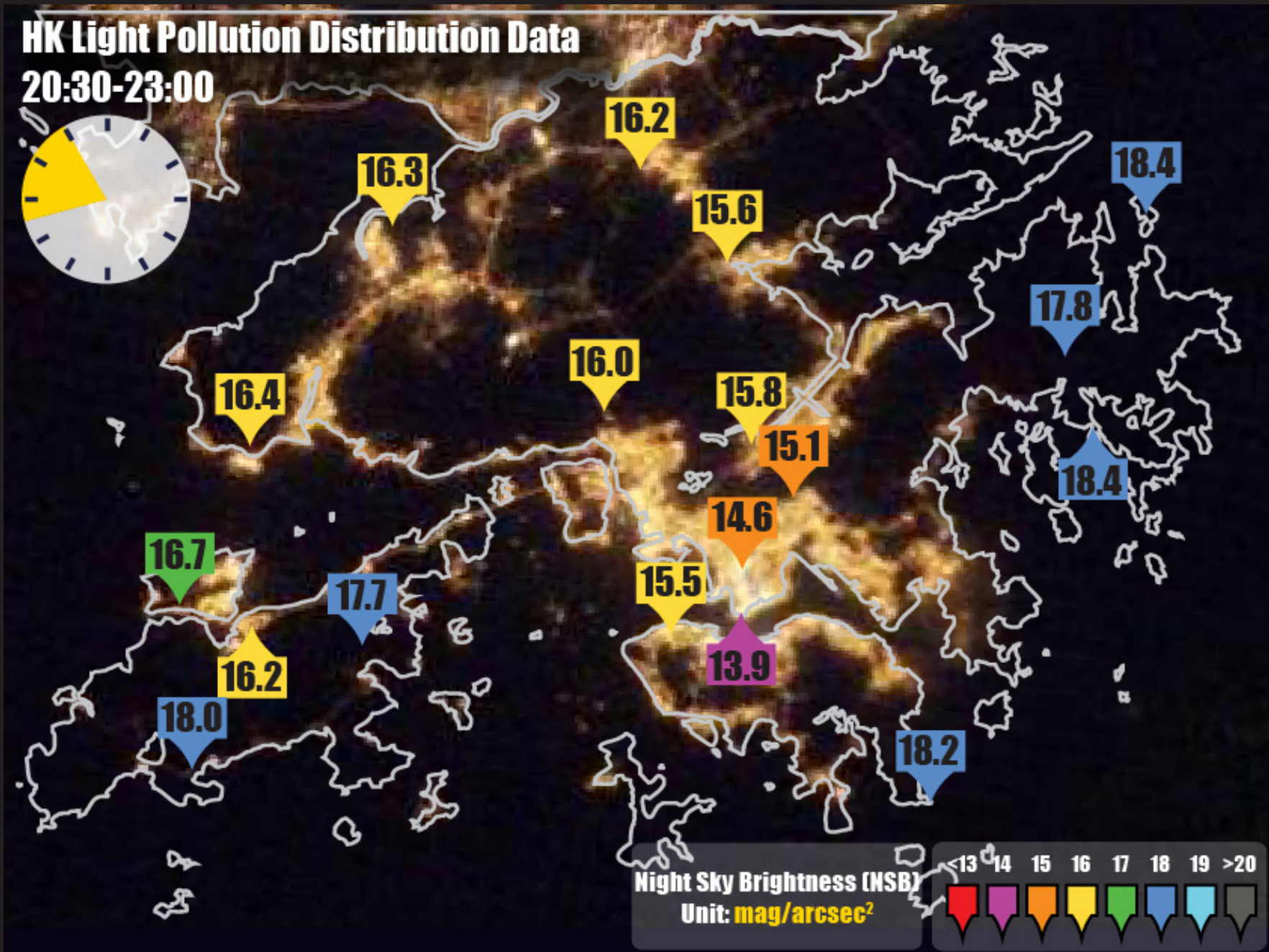


figure 11: Hong Kong Light Pollution Distribution Map, Hong Kong Night Sky Brightness Monitoring Network

research design, methods, and data collection- con't

human health. For example, the Highway Department of Hong Kong suggested that all traditional light bulbs in street lights should be changed to LEDs, in order to save energy [Highway Department, 2013]. However, according to a research done at the University of California, Irvine (UCI) , most LEDs that are being used in lightings, such as Christmas lights and traffic lights, contain a large amount of lead which “exhibit significant cancer and noncancer potentials” [Scheer & Moss, 2012]. The report has also stated that, although white LEDs contain less lead, the amount of nickel found in those lights can cause “allergic reactions in as many as one in five of us upon exposure” [Scheer & Moss, 2012]. The department has mentioned light pollution in section 8.6.1 of its Public Lighting Design Manual [2006]; however, all it says is that “light above the horizontal should be minimized because it is wasteful” [Public Lighting Design Manual, 2006], which is not providing any solid guidelines on how to reduce the problem of light pollution [Appendix A]. Moreover, the design manual has no recommendation on using shielded light to reduce light from spilling upward. According to the Dark Sky Society [2009], light fixtures should be shielded to reduce glare and light trespass, and hence, provide a better vision at night [Appendix B].

research design, methods, and data collection- con't

The current guidelines on advertisement signage do not consider the effect of signs with lights on human health. The Buildings Department, which regulates all overhanging signs constructions, puts the overall structure of the street as their priority, aims to provide enough space for on-going traffic (including pedestrians and vehicles) and to maintain a sturdy signboard structure (Buildings Department, 2015). Figure 13 shows the existing recommendations on overhanging signboards (Buildings Department, 2015).

With the Hong Kong Light Pollution Map (figure 11) created by the Hong Kong Night Sky Brightness Monitoring Network (NSN), three streets with high light pollution rate were identified and sample designs were done on those chosen streets. The map was created with a gadget named Sky Quality Meter, which is a portable device being used to measure the brightness of the sky. The reading unit is magnitude per square arcsecond (mag/arcsec²). The smaller the reading, the brighter the sky is (i.e. more light from the city has emitted to the sky). From that, Tsim Sha Tsui, with a reading of 13.9 mag. arcsec²) has been identified as the spot that has the worst light pollution problem in Hong Kong. According to the NSN, the night sky of Tsim Sha Tsui is a thousand times brighter than a night sky without any pollution (Pun, 2013). The reason why Tsim Sha

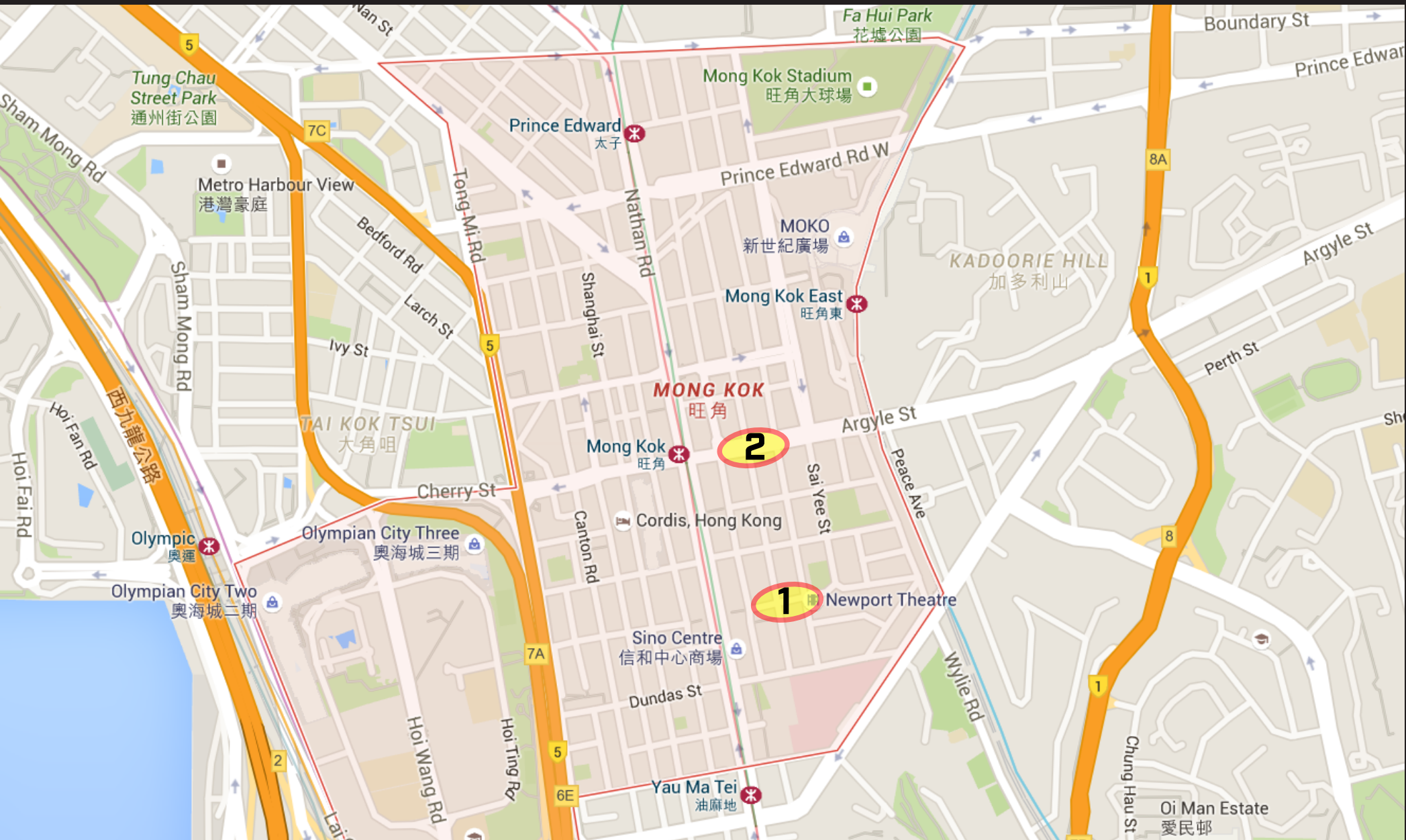


figure 12: Mong Kok, Google Map
sample 1: Soy Street; 2: Argyle Street

research design, methods, and data collection- con't

Tsui has the worst light pollution problem in Hong Kong is because of a light show, The Symphony of Light, which happens there every night. The show is one of the most popular tourist attractions, and is also the biggest permanent light and sound show in the world. However, light pollution resulting from the show was not part of the focus of this research. The next spot that has the second worst light pollution problem was Mong Kok (14.6 mag/arcsec²). Mong Kok is one of the oldest commercial centers of the city, with a variety of shopping malls and restaurants. Besides being a commercial hotspot, it is also the most populated area in Hong Kong, which contains a lot of residential buildings that are at the upper floors of retail stores. Neon signs and other advertisement signs with lights are very common within the area.

Two streets in Mong Kok were then picked to apply new guidelines as sample designs: Soy Street and Argyle Street (indicated as 1 and 2 respectively on figure 12; also see figure 14 and 15). These two streets were chosen among the others because they both contains overhanging advertisement boards with lights. Besides that, the streets also have different characteristics when serving the city. Soy Street (figure 14) is a narrow

research design, methods, and data collection- con't

street with only two one-way driveways. Small local businesses are located on both sides of the street, and old residential units are at the upper floors of the stores. Argyle Street (figure 15) is an opposite of Soy Street. It is a wide, main street of the area. It has three lanes for each direction of vehicle roadways, and bigger commercial buildings and malls located on both sides of the road.

Next, existing condition of the two chosen streets were being examined with Google Earth street view. New guidelines were then being applied to the streets. After applying, benefits of the new scenarios were calculated. The calculation is mainly focusing on the numbers of household that will be benefiting from the design. This is done with the Population Census Data in Hong Kong (Population Census, 2011).

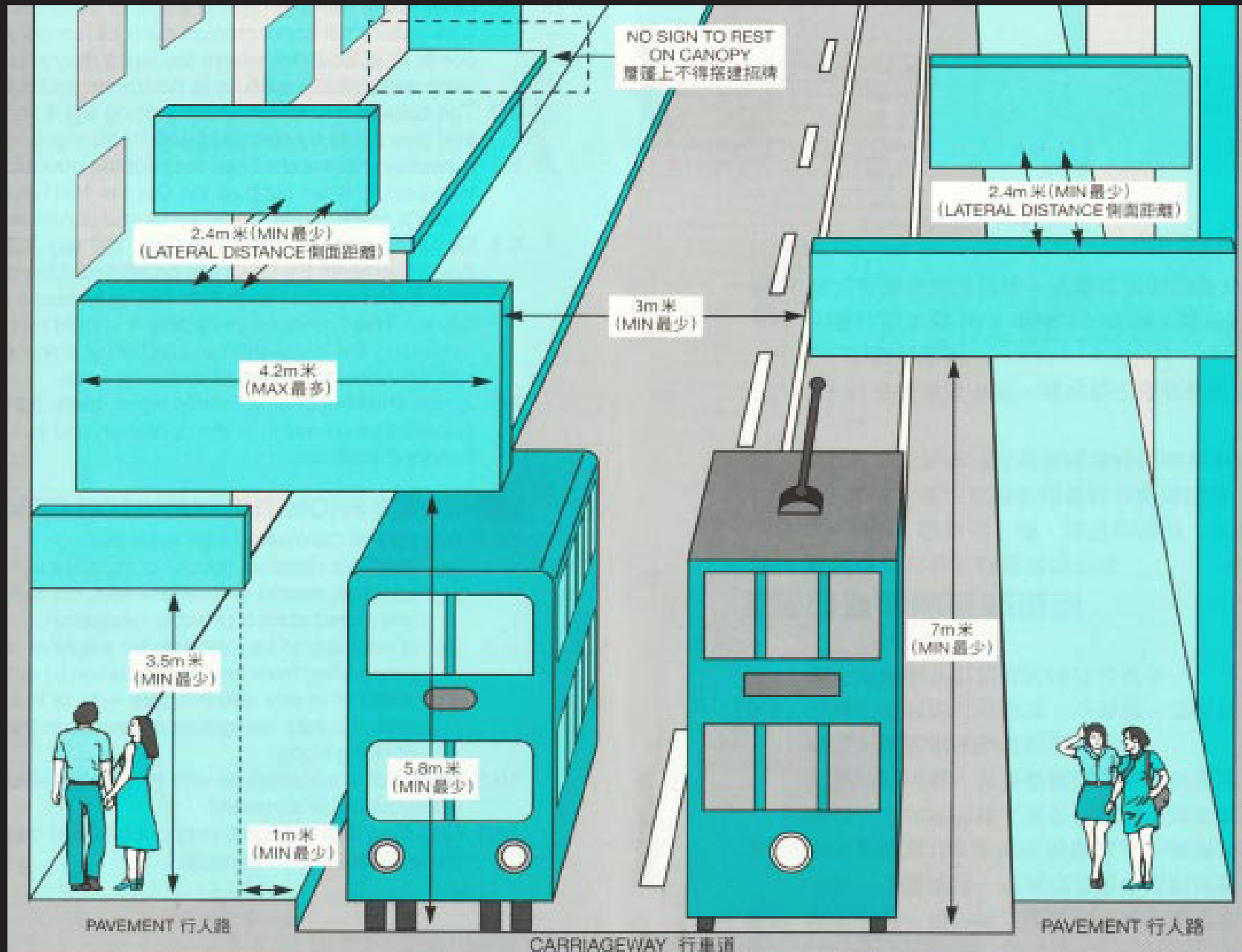


figure 13: Projection and Clearance of Signboards, Hong Kong Buildings Department





figure 15: Argyle Street, Google Street View

design investigation and analysis

The current lighting design guideline in Hong Kong focuses mainly on safety of both the structure itself and night vision of pedestrians and vehicles. However, as Dr. Pun, Science professor at the University of Hong Kong, told the CNN, “In Hong Kong, the government tends to play things on the safe side ... Certainly, I’m all for safety -- these are extremely important issues -- on the other hand, when you go near some public places, city parks for instance, they are lit up like the daytime in the evening” (CNN, 2013), lightings in Hong Kong are going on an extreme because the government wants to make sure they have provided their people with more than enough lights in order for them to be safe at night. The new lighting design guideline aims to provide only enough lighting for the public to avoid affecting residents’ homing experiences.

After analyzing the flaws of the current Hong Kong lighting design requirements, and with the help of existing design recommendations from other cities, a new list of lighting design guidelines specifically for Hong Kong is created:

design investigation and analysis- con't

1. Reduce height of street light posts

- a. For streets that are less than five-lane, height of light posts should be reduced to 15'
- b. For streets that are five to six-lane, height of twin-central light posts can go up to 20'
- c. For streets that are seven-lane or more, height of twin-central light posts are allowed to go up to 30' (see point 2)
In the areas that include tram routes, light posts heights are allowed to go up to 20'

rationale:

The goal of this recommendation is to shorten the light travelling distance between the light sources and the ground, in order to reduce light spill and light trespass. Minimum height restrictions are based on the common height of fire trucks in Hong Kong, which is 12.8', and height of trams, which is around 15'.

design investigation and analysis- con't

2. Light posts arrangement

- a. One-lane street: Single sided placement
- b. Two to three-lane street (including any street parking spaces): Staggered placement, a.k.a. zigzag
- c. Four to six-lane street: Twin-central placement
- d. Seven-lane or more: A combination of twin-central and staggered placement; under this situation, the twin-central light post is allowed to be taller in height (see point 1)

rationale:

Adjustment made on existing requirements from the Public Lighting Design Manual (2006).

design investigation and analysis- con't

3. Single sided light posts should be installed on the walkway as far from the residential building as possible (i.e. close to the edge of walkway)

- a. Follow the recommendations in section 8.4.3 of the Public Lighting Design Manual on accomodating with existing trees and stores (2006)

rationale:

According to the Dark Sky Society, light fixtures should not be installed closer to the building than four times of the height of the fixture (2009); however, due to the narrow size of street in Hong Kong, it is impossible to accomplish this, so reasonable adjustment according to the characteristic of the city is done to minimize the negative effect of light trespass from light fixtures.

4. Reduce sizes of signs

- a. length to no more than 80% of the width of walkway

rationale:

To avoid light trespass into apartment units.

design investigation and analysis- con't

5. Reduce height of sign installation

- a. Top of sign should not be beyond 50% of the space between top of commercial unit and bottom of first floor residential unit.
- b. Height restriction of signs with lights on both sides of the street should follow whichever building has the lower floor of residential units, if street in between is three-lane or less. E.g. If a building has both the ground floor and first floor as commercial use, but the building across from the street has only the ground floor as commercial use, the heights of lit-up signs on both buildings should follow the heights of the building that has a lower floor as residential unit.

rationale:

Currently, Hong Kong does not have any restriction on maximum height of sign installation (figure 10), resulting in huge neon signs or spot lights installed right outside of residential units. This guideline is to ensure the clearance of residents' windows views and to reduce/eliminate light trespass from those signs into the indoor.

design investigation and analysis- con't

6. Spot lights should be shielded and pointing downward

rationale:

According to the Dark Sky Society, lights should be shielded (Appendix B) to avoid light spill (2009).

7. Spot lights should be reaching no more than 3' away from the sign that they are intended to light up

rationale:

Referencing Qianhai Planning Standard and Guideline (2016)

8. Location of signs with lights

rationale:

- a. Signs (both neon and spot lights) cannot go beyond first floor residential: e.g. when the first two floors of a residential building is being used as commercial, signs cannot be installed beyond the top of the second floor (Also applies to any commercial buildings that are a street across from the residential building, if the street is three-lane or less)

See rationale for guideline 5.

design investigation and analysis- con't

9. Adding green buffers

- a. When walkway is 10' or wider, a 3' buffer of 3' height shrubs between roads and walkway should be installed

rationale:

Currently, Mills barriers are used to separate pedestrians and vehicle traffic. This setting is to prevent people from jaywalking. However, those Mills barriers have no benefit in terms of reducing glare. To reduce glare created by headlights from vehicles to pedestrians, a green buffer of shrubs is suggested to replace the Mills barriers.

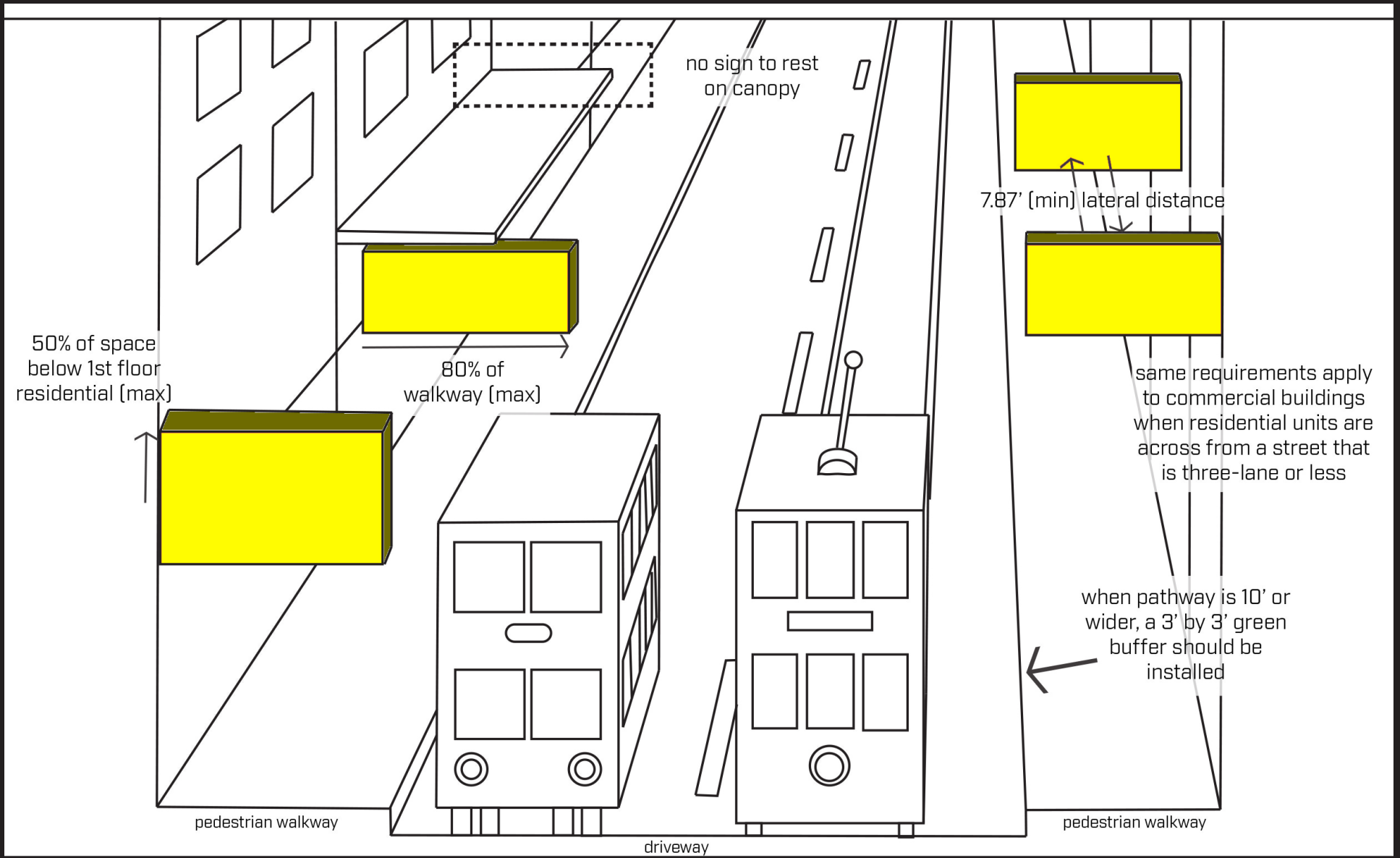
design investigation and analysis- con't

10. Adding pedestrian lighting

- a. When street is four to six-lane, wall sconces should be installed at 7' from ground, spacing at most 35'; wall sconces should be shielded and pointing downward

rationale:

According to Holladay et. al, lights that are installed at more than 30 degree from eye level when a person is standing at a distance of his/her height to the light source (e.g. when a person who is 6' tall is standing 6' away from the light source, the light source should be at least 30 degree from that person's eye level) in order to minimize glare. The average height of Hong Kong people is around 5'6" (Statista, 2008).



design investigation and analysis- con't

To better show the application of the above guidelines to an actual street of Hong Kong, two streets in Mong Kok have been chosen to be sample sites. In figure 17, the application to Soy Street is shown. The two buildings on both sides have their ground floors as commercial use (a butcher shop and a pharmacy), but the building on the left has its first floor also as commercial (a restaurant). Since the driveway on Soy Street is has only two lanes, the installation height of the signs on both buildings have to follow the one that has a lower floor of residential units (i.e. the building on the right). In figure 18, which shows application of new guidelines on Argyle Street, the non-overhanging sign with spot lights that is above the ground floor pharmacy is currently installed right below the first floor residential of that building. Spill light will cause light trespass into residential units and affect residents. Shorten the reaching distance of those spot lights and lower the installation height will highly reduce those distractions to residents.

residential

residential

restaurant

residential

residential

butcher shop

pharmacy

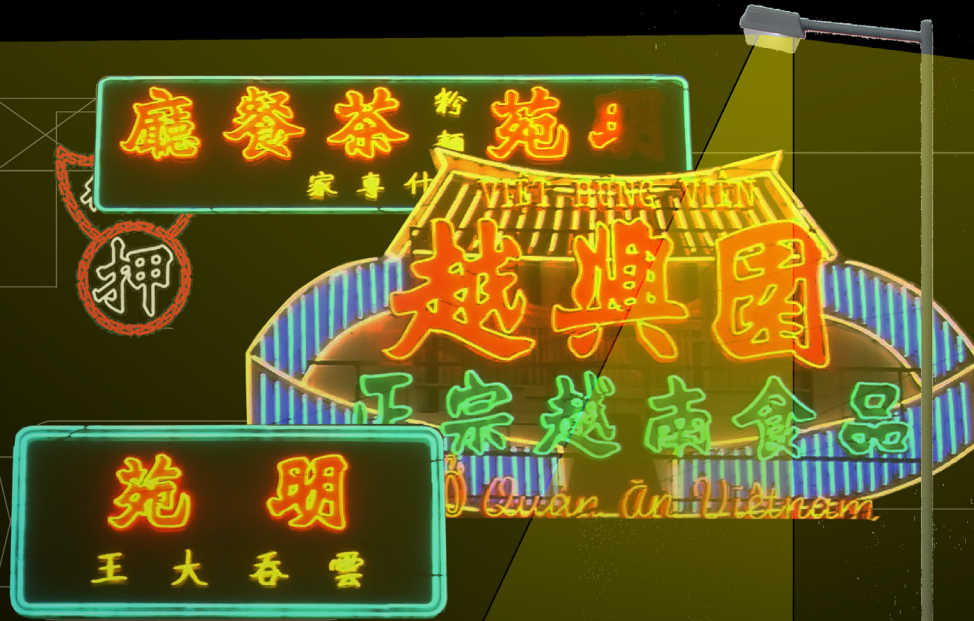




figure 17: Soy Street Application, Stephanie Lau
 left: existing condition; right: new guidelines applied

residential

residential

residential

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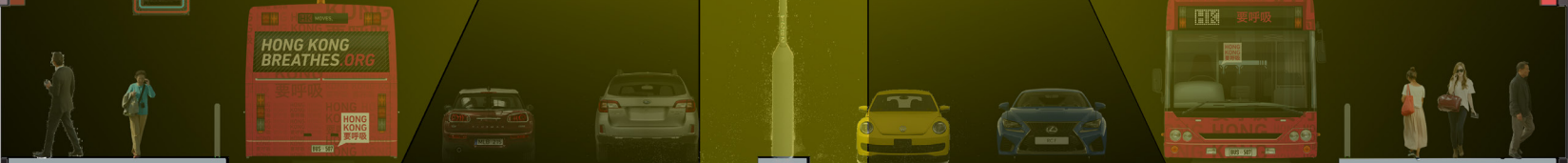
residential

residential



pharmacy

boutique



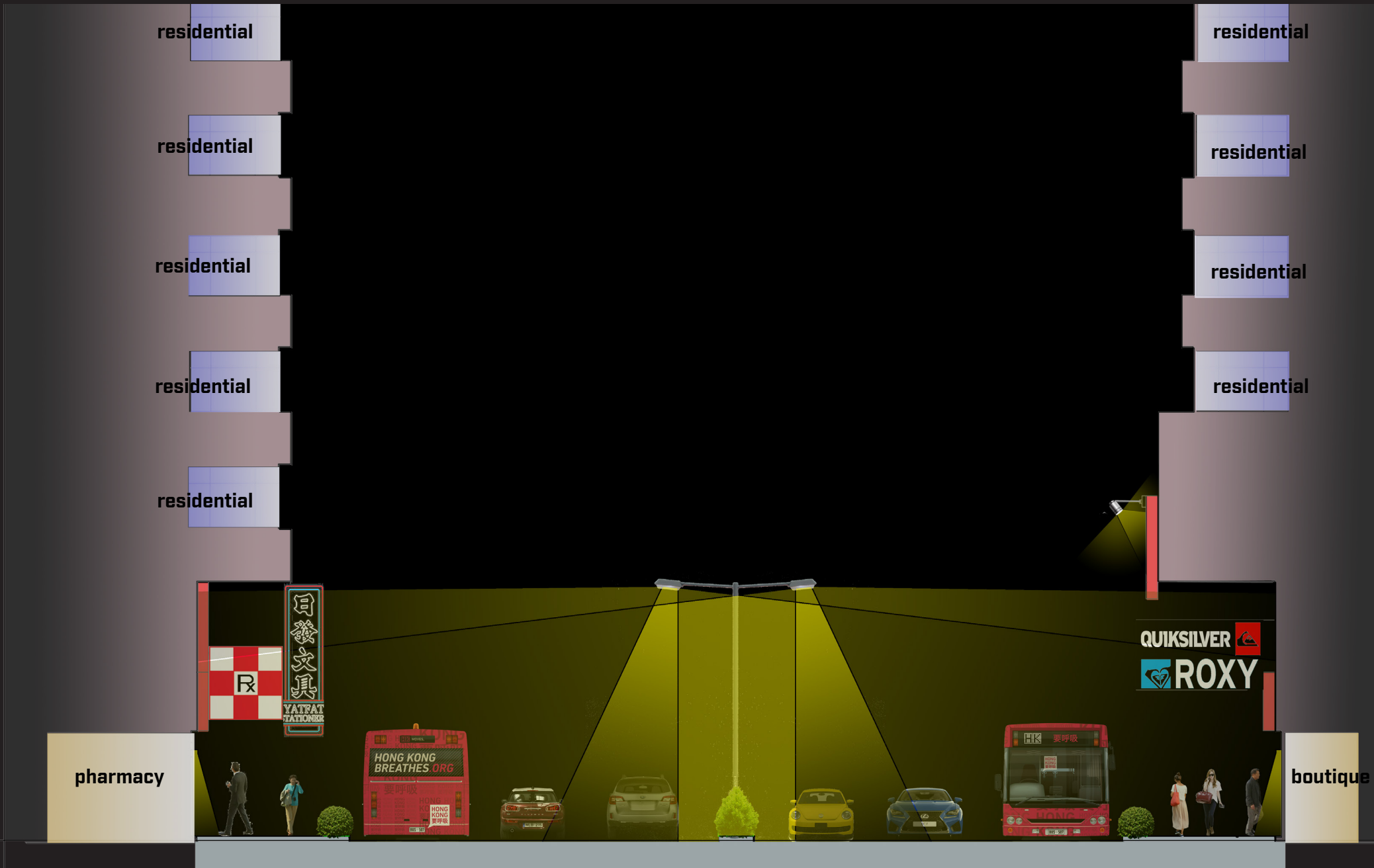


figure 18: Argyle Street Application, Stephanie Lau
 left: existing condition; right: new guidelines applied

reflection and conclusion

Light pollution not only affects the ecological system, but also the lives of people living in dense, highly lit cities. Of course, it is often better to provide more than less, but this is not always the case. Providing more than enough lighting is wasting a lot of energy, and those wasted light (i.e. spill light) is highly affecting living quality of human. While designing lighting in a city, one should also take this into consideration.

According to the Population Census Data of Hong Kong, there are 67,078 people living in 25,883 apartment units in Mong Kok (2011). The area has a total number of 248 residential buildings, and each apartment unit has around 2.5 residents (2011). Assuming all the flats on the first two floors of each building are currently being affected by the problem of light pollution. After completely applying the new guidelines suggested in this report, around 4,960 people (i.e. 1,984 households) will be benefited by the new lighting design requirement.

As mentioned previously, light pollution in Hong Kong stems largely from the culture of the city. In order to make the new guidelines more acceptable to the public, government should set up a mandatory policy to support them. For example, starting from 2020, any

reflection and conclusion - con't

businesses that go out of business should also take off any signs with light they might have, if the signs are not meeting the new lighting requirements; any businesses that would like to add any signs will need to install them according to the new guidelines.

Identification and preserve of neon signs that are significant to the culture are also important steps that are recommended. As most of the neon signs have been hanging at their spots for decades, residents are emotionally attached to them. Anyone who considers applying the new guidelines should take their time to understand the meaning of each sign before eliminating it. If there is a sign that is being identified as a significance to the culture of the community, one should make adequate adjustment to the existing signage in order to keep the problem of light pollution that particular sign is producing to minimum.

Furthermore, the government should consider adding any lighting design policies into the law. For right now, the lighting design requirements are mostly voluntary. In order to efficiently reduce the impact of light pollution to Hong Kong residents, law enforcement should be involved.

appendix

appendix A:

Public Lighting Design Manual Section 8.6.1

8.6.1 Glare Control and Avoidance of Light Pollution

Disability glare reduces the contrast between objects and their background, impairing the vision. An object that is just visible when there is no disability glare will in the presence of disability glare, merge into the background. The percentage by which the background luminance has to be increased to make the object just visible again is known as the threshold increment (TI).

The presence of disability glare can be reduced by the use of curved temper glass (CTG) or flat glass (FG) lanterns instead of bowl type lanterns, either of moderate or low threshold increment (MTI/LTI) lanterns. A CTG or FG luminaire generally meets the recommendation for the TI being not more than 10%, and more pronouncedly limits the glaring effect at low mounting height close to the road.

In slopes with a gradient in excess of 10%, lanterns shall be rotated at the spigot entry to suit the slope so as to control the glare. It is also beneficial to do this on straight long section of a sloped road in order to maintain the longitudinal uniformity. It would be too glaring when driving up and too patchy when driving down a slope if the lanterns are not rotated accordingly. In addition, there is no special lighting problem at a dip but it is necessary to limit glare from luminaires beyond a crest by siting the lights to appropriate locations.

Light pollution, whether it keeps someone awake through bedroom window or impedes his view of the night sky, is a form of pollution. Sky glow is another form of pollution. Glare, the uncomfortable brightness of a light source when viewed against a dark background, light trespass and the spilling of light beyond the boundary of the property on which the source is located are other forms of light pollution.

In order to reduce light pollution, light above the horizontal should be minimized because it is wasteful, it may cause a nuisance by shining through bedroom windows and it contributes to sky glow.

appendix B: Diagrams of Acceptable/Unacceptable Lighting Fixtures

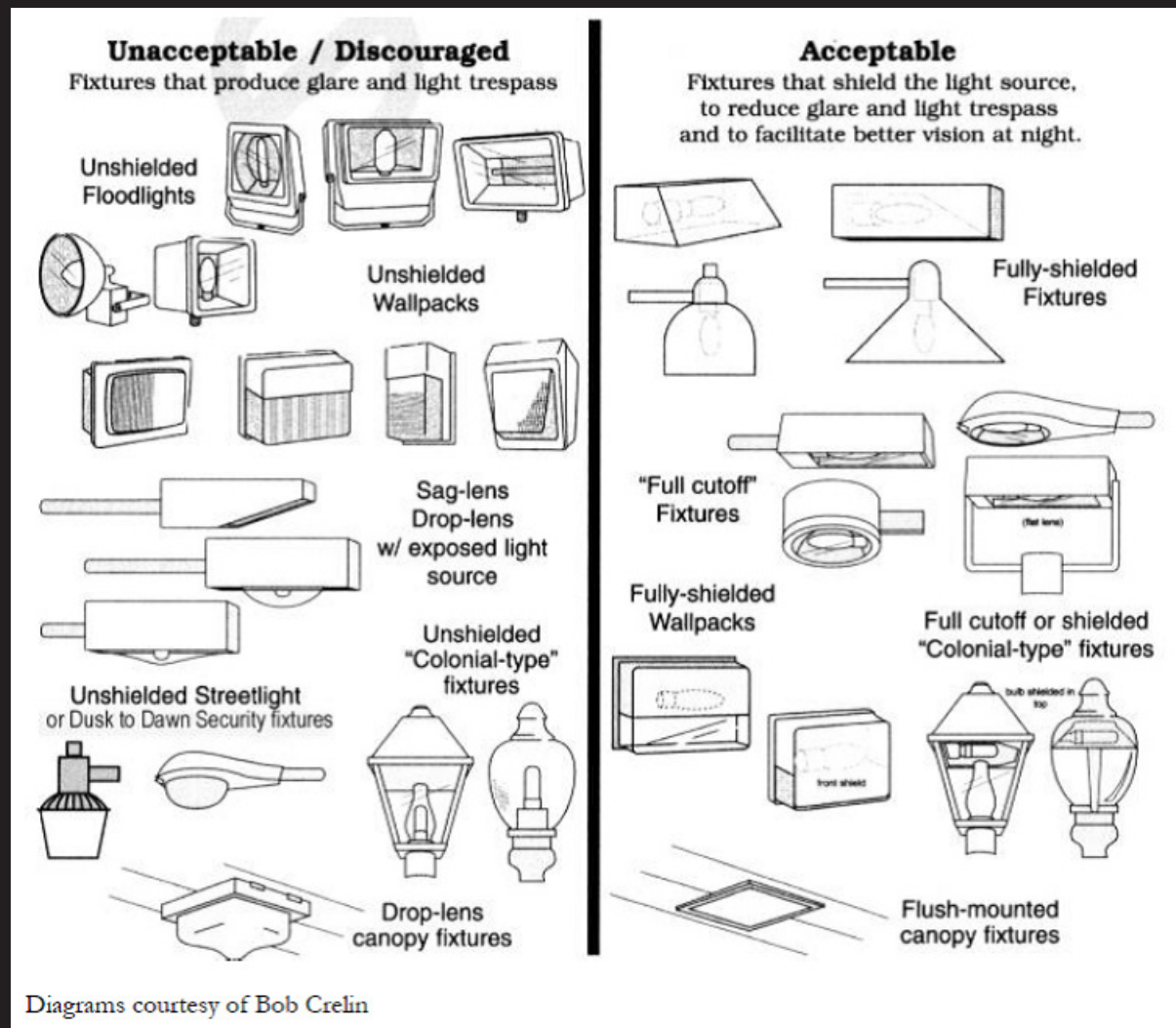


figure 19: *Diagrams of Acceptable/Unacceptable Lighting Fixtures*, The Dark Sky Society

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thank you.



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