sustainability

MDPI

Review

A Comparative Study on Current Outdoor Lighting Policies in China and Korea: A Step toward a Sustainable Nighttime Environment

Wu Guanglei, Jack Ngarambe and Gon Kim *

Department of Architectural Engineering, Kyung Hee University, Yongin 17104, Korea
* Correspondence: gonkim@khu.ac.kr

Received: 22 March 2019; Accepted: 16 July 2019; Published: 23 July 2019

Abstract: Light pollution is a serious environmental issue with many adverse effects on human health and the ecosystem as a whole. Accordingly, many countries have issued laws and regulations to limit the effects of artificial lighting at night (ALAN). The Republic of Korea and China are among the few countries that have drafted laws to curb light pollution. In the present study, we gathered data related to light pollution regulations and ordinances in both China and Korea. We then carried out a comparative analysis of the light pollution laws of both countries. We found that, although the two countries share a similar socio-economic background, they have different approaches to the issue of light pollution. The information provided in this study serves as a guideline to countries that wish to develop their own light pollution policies. In addition, the conclusions provided in our study offer potential improvements to local and national light pollution policies in both the Republic of Korea and China.

Keywords: light pollution; ULOR; lighting intensity; outdoor lighting measurements; local laws; landscape lighting; decorative lighting

1. Introduction

Light pollution is one of the most rapidly increasing forms of environmental degradation. There is increasing evidence that draws potential linkages between artificial light at night (ALAN) and certain human health conditions. For example, a study by Rybnikova et al. [1], based on World Bank databases, reported a statistically significant association between ALAN and prostate cancer incidence. A potential correlation between outdoor LAN and breast cancer incidence was also reported by Peter et al. [2]. In addition, ALAN has been linked to diabetes [3], fatigue, and depression [4]. In addition to the effects of ALAN on the well-being of humans, sky glow resulting from ALAN is a major interference to astronomical activities [5,6]. Furthermore, excessive and unnecessary ALAN is a key contributing factor to energy waste [7].

As such, these rapidly increasing adverse effects of ALAN on humans and the general interactions between ecosystems have led to subsequent legal actions against improper usage of light, especially at night. The involvement of governmental institutions, in the form of ordinances or laws against ALAN, has increased over the years [8]. Light pollution laws, ordinances, and prescriptive measures are becoming common in many parts of Europe [9], Asia [10,11], and America [12].

Although the effects of ALAN are primarily the same in all areas, different countries have adopted diverse legal approaches to reduce light pollution. For example, as discussed by Martin-Taylor [13], the United Kingdom has extended the previously existing law on air pollution to include light pollution. Many Italian regions have employed individual ordinances to prevent or reduce specific light-related issues prevalent in given regions [14]. There is a variety of factors that influence the type of light

pollution laws employed by a country or region. For instance, bolt-on laws are likely to be less expensive than stand-alone laws adopted for the specific issue of light pollution [12]. In addition, ordinances are likely to provide better solutions in countries with cities or regions that experience diverse forms of light pollution [14]. China and Korea are among the countries that recently established light pollution preventive measures through city ordinances. Given the social similarities between China and Korea, which may give rise to similar artificial lighting trends, the current study provides a comparative analysis of the Seoul light pollution ordinance and the regional light pollution laws and preventive measures in China. The contents of this study provide an extensive technical guideline to countries or regions that wish to draft their own regional or city-based light pollution laws.

2. Methods

A literature review plays a key role in the field of scientific development [15]. In order to better understand the background of the light pollution policy in China and South Korea, this study searched for relevant information on the website of the Chinese People's Congress, the site of the Shanghai People's Government, the site of the Guangzhou People's Government, Beijing People's Government site, Tianjin People's Government website, and other related websites using the search term "light pollution policy, light pollution law, and light pollution ordinance". We also searched for the legal administration services website in Seoul, South Korea. Furthermore, we used a lot of relevant literature from Google Scholar, MDPI, Elsevier, and other related literature search engines to provide constructive opinions.

3. Seoul Light Pollution Ordinance

The Seoul metropolitan government enacted an ordinance on the prevention and management of light pollution, herein referred to as the ordinance, on 15 July 2010. The purpose of the ordinance is to improve the quality of life for citizens, protect ecosystems, and save energy by preventing unnecessary lighting practices. It is applied under three categories of lighting practices: Space lighting, advertisement lighting, and decorative lighting. In addition, the ordinance classifies all areas in Seoul into four classes based on land usage as dictated by the Korean Ministry of Transport [16]. These classes are known as "light environment management zones". The idea behind light management zones is to allow different levels of lighting in areas that serve different purposes; for instance, lighting levels in a commercial area should be relatively higher than those in a residential area. Permissible lighting levels are, therefore, provided for lighting in each of the four land use categories. Table 1 shows the classification of areas in the city of Seoul based on land usage.

Table 1. Classification of areas for lighting management.

Light Environment Management Zone	Description
Class 1	Green areas for conservation
Class 2	Natural green areas and productive green areas
Class 3	Residential areas
Class 4	Semi-industrial and commercial areas

3.1. Space Lighting

Space lighting includes any type of lighting installed for the purpose of facilitating safe and pleasant nighttime activities and consists of security and road lighting. The Seoul light pollution prevention ordinance specifies the maximum vertical illuminance value for space lighting in each of the four light management zones (illuminance is a measure of photometric flux per unit area or visible flux density. Illuminance is measured in either lux (lm/m^2) or foot candles (lm/ft^2) [17]). This facet of the ordinance mainly addresses light pollution, in the form of light trespass, intruding into enclosed areas at night. Table 2 shows permissible luminance values dictated by the Seoul light pollution ordinance.

Table 2. Permissible luminance values for space lighting.

Light Environment Management Zone	Class 1	Class 2	Class 3	Class 4	
				Semi-Industrial Area	Commercial Area
Maximum vertical illuminance / [lux]	<10	<10	<10	<25	<25

3.2. Advertisement Lighting

The ordinance defines advertisement lighting as lighting devices installed outdoors for advertising purposes [16]. The ordinance provides lighting maximum luminance values that are legally accepted in each light management zone. Table 3 shows the allowable luminance values for advertisement lighting (luminance (Lv) is the density of visible radiation (photopic or scotopic) in a given direction, measured in lm/m^2/sr) [17].

Table 3. Permissible luminance values for advertisement lighting.

Light Environment Management Zone	Class 1	Class 2	Class 3	Class 4	
				Semi-Industrial Area	Commercial Area
Maximum luminance / [cd/m^2]	<50	<400	<800	<900	<1000

3.3. Decorative Lighting

Decorative lighting refers to outdoor lighting installed for decorative or recreational purposes [16]. The ordinance provides lighting limits for decorative lighting in the form of mean and maximum permissible luminance values. Table 4 shows the allowable lighting levels for decorative lighting.

Table 4. Permissible luminance values for decorative lighting.

Light Environment Management Zone	Class 1	Class 2	Class 3	Class 4	
				Semi-Industrial Area	Commercial Area
Maximum luminance/ [cd/m^2]	<20	<60	<180	<240	<300
Mean luminance / [cd/m^2]	<5	<5	<15	<20	<30

4. The laws of China

Attention to light pollution is a recent activity in China, and theoretical research results are relatively limited. Light pollution prevention legislation is also scarce. So far, China has not issued special light pollution preventions or control legislation. The current law has failed to effectively solve China's current light pollution problems. Therefore, it is necessary to evaluate the status quo of China's light pollution prevention legislation.

4.1. Relevant Provisions of the Constitution of the People's Republic of China

According to Article 26 [18], "The state protects and improves the environment in which people live and the ecological environment. It prevents and controls pollution and other public hazards". This provision can be regarded as the basis and premise for all laws and regulations on environmental pollution prevention, but it is only a principled provision of the general outline. It does not specify which types of pollution should be controlled. The expression of "other public hazards" is also vague. It cannot be used as a direct legal basis for relief.

4.2. Relevant Provisions of the General Principles of the Civil Law of the People's Republic of China

According to Article 83 [19], "In the spirit of helping production, making things convenient for people's lives, enhancing unity and mutual assistance, and being fair and reasonable, neighboring users of real estate shall maintain proper neighborly relations over such matters as water supply, drainage, passageway, ventilation, and lighting. Anyone who causes obstruction or damage to his neighbor, shall stop the infringement, eliminate the obstruction, and compensate for the damage". Article 83 is a provision on the principles of neighbor relations. The law states that it is necessary to correctly deal with the problem of "lighting" in neighbor relations. The so-called "lighting" means that the light is sufficient without interference from external adverse factors and harmful light. In the current case of light pollution, the court's judgment is mostly based on neighbor relations. Therefore, it is not difficult to see that the limitations of the law in application of the case must first satisfy the condition of occurrence between adjacent real estate. This makes the neighboring right seem to be a little powerless in the relief of light pollution.

4.3. Relevant Provisions of the Property Law of the People's Republic of China

According to Article 90 [20] , "An oblige of immovable shall not, in violation of State regulations, discard solid waste or discharge hazardous substances, such as air and water pollutants, noises, and optical and electromagnetic radiation". In the legislation, the Property Law is the first to incorporate light pollution into the scope of legal regulation. It strictly prohibits destruction of the light environment and sets mandatory restrictions for emitted light. However, the provisions on light pollution in this article are too simple and have obvious limitations. This article stipulates that "obligations" are mainly restricted to real estate owners, and light pollution regulations in China require further improvement.

4.4. Relevant Provisions of the Environmental Protection Law of the People's Republic of China

According to Article 24 [21], "Units that cause environmental pollution and other public hazards shall incorporate the work of environmental protection into their plans and establish a responsibility system for environmental protection, and must adopt effective measures to prevent and control the pollution and harm caused to the environment by waste gas, wastewater, waste residues, dust, malodorous gases, radioactive substances, noise, vibration, and electromagnetic radiation generated in the course of production, construction, or other activities."

4.5. China's Local Laws and Regulations

Although China lacks national laws and regulations on light pollution prevention, the government has introduced many measures to prevent and control light pollution. Table 5 summarizes the lighting specifications issued by four different cities and the regulations and targets related to light pollution. Table 6 summarizes relevant preventive measures and related standards from relevant specifications. These standards illustrate which cities provide more comprehensive and effective measures.

Table 5. Some of the existing regional ordinances against light pollution.

Country	City/Province	Year of Enforcement	Title	Purpose	Departments
China	Shanghai	2011	Measures for the management of glass curtain walls of buildings in Shanghai	To reduce the environmental impact of light reflection and ensure social and public security	Shanghai Municipal People's Government
		2012	Specifications on Urban Environment (Decoration) Lighting	To provide safety, environmental protection, and energy saving	Shanghai Municipal Bureau of Quality and Technical Supervision
		2013	Limits and measurement methods of maximum visible brightness for public places' light emitting diode (LED) panels	To reduce light pollution and interference caused by LED displays and to save energy	Shanghai Municipal Bureau of Quality and Technical Supervision
	Tianjin	2013	Tianjin City Lighting Management Regulations	To improve lighting environments and save energy, while ensuring economic prosperity	Tianjin Municipal People's Government
	Guangzhou	2014	Guangzhou light radiation environment management specifications (draft for comment)	To strengthen the management of light spillage, protect public health, and improve the ecological environment	Guangzhou Environmental Protection Bureau
		2014	Guangzhou outdoor advertising and signboard management methods	To manage outdoor advertisement signboards and to beautify the environment	Guangzhou Municipal People's Government
		2017	Guangzhou building glass curtain wall management measures	To reduce the environmental impacts of light pollution and to ensure public safety	Guangzhou Municipal People's Government
	Beijing	2006	Technical specification of urban nightscape lighting	To provide safety, environmental protection, and energy savings	Beijing Municipal Administration of Quality and Technology Supervision

Table 6. Light pollution prevention measures in various cities.

Strategy	City/Province			
	Shanghai	Tianjin	Guangzhou	Beijing
Urban environmental brightness area division	Yes·	N/A	Yes	Yes
Prevention and control of light pollution in urban environmental lighting	Yes	Yes	Yes	Yes
The maximum value of the upward light output ratio (ULOR) on the luminaire	Yes	N/A	N/A	N/A
Residential lighting	Yes	N/A	Yes	Yes
Public area lighting	Yes	N/A	Yes	N/A
Commercial center lighting	Yes	N/A	Yes	N/A
Administrative office lighting	Yes	N/A	N/A	N/A
Building exterior lighting	Yes	N/A	Yes	Yes
Greenbelt and square landscape lighting	Yes	N/A	Yes	N/A
Illumination of rivers, bridges, ponds, fountains, and other water bodies	Yes	N/A	N/A	N/A
Advertising, signage, display, and logo lighting	Yes	N/A	Yes	N/A
Limits and measurement methods of maximum visible brightness for public places light emitting diode (LED) panels	Yes	N/A	Yes	N/A
Contravention fines	N/A	N/A	Yes	N/A

4.5.1. Urban Environmental Brightness Area Division

According to CIE (Commission Internationale de L'Eclairage) [22], there are four types of environmental regions; namely, a naturally dark environmental region, a low-brightness environmental region, a medium-brightness environmental region, and a high-brightness environmental region, as detailed in the "Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations". Shanghai, Guangzhou, and Beijing also use the division of environmental areas to understand night lighting design and light radiation environmental management [23–25]. Only Tianjin does not categorize brightness areas. Table 7; Table 8 show the division of urban environmental brightness.

Table 7. Division of urban environmental brightness in Shanghai.

Environment Zones	Natural Dark Environment	Low Light Environment	Moderate Light Environment	High Light Environment
Code	**E1**	**E2**	**E3**	**E4**
Description	National parks, nature reserves, and observatories	Suburbs and residential areas	Areas outside the sub-center of the city and corresponding residential areas	City center and business district of the sub-center

Table 8. Division of urban environmental brightness in Beijing.

Environment Zones	Low Light Environment	Moderate Light Environment	High Light Environment
Description	Residential area, leisure area	Common area	Urban center, commercial center

4.5.2. Prevention and Control of Light Pollution in Urban Environmental Lighting

In the prevention and control of light pollution in urban environmental lighting, the laws of Shanghai are clearly against direct light falling into residential buildings. All lighting facilities opposite residential buildings must take corresponding measures to prevent stray light from entering a home. To achieve this goal, building decoration materials should not use floodlighting materials [23]. According to paragraph 2 of article 14 of the Tianjin City Lighting Management Regulations, the establishment of urban lighting facilities shall conform to the control standards of light pollution and shall be coordinated with the surrounding environment [26]. Guangzhou Municipality stipulates that outdoor advertising, sign lighting, etc., should strictly abide by national and local lighting design standards, technical specifications, and light environment control zoning, and a rational selection of lighting sources, lamps, and lighting methods is necessary to reduce the effects of artificial lighting on the environment [24]. Beijing has also imposed restrictions on artificial lighting at night. The specification proposes that light trespass and light interference be considered in the design of lighting systems [25].

4.5.3. The Maximum Value of the Upward Light Output Ratio (ULOR) on a Luminaire

To better view the night sky, the brightness of the earth atmosphere must be reduced, so the upward light output ratio (ULOR) of outdoor lamps is important. Shanghai has a standard for the ULOR of different areas. Only Shanghai has this standard among many cities [23]. Table 9 shows the maximum ULOR of luminaires in Shanghai (the upward light output ratio, sometimes called "upward efficiency of the luminaire", is the fraction of the luminous flux emitted by the lamp going outside the luminaire in the upward direction. It is expressed in per cent [26]).

Table 9. The maximum upward light output ratio (ULOR) of luminaires in Shanghai.

Environment Zones	E1	E2	E3	E4
The maximum upward light output ratio (ULOR) of a luminaire	1	5	10	25

4.5.4. Residential Lighting

Regarding residential lighting, Shanghai, Guangzhou, and Beijing have corresponding regulations, but Tianjin does not. A residential area is a low-light area with low illumination. Shanghai limits the maximum vertical illumination on the surface of a residential building's windows and the maximum light intensity for luminaires that point to the windows of the residential building. This effectively controls the impact of public road lighting [23]. Guangzhou has drafted light radiation environmental management specifications (draft for comment). Lighting-related restrictions in residential areas

have not been separately proposed. However, prohibition of housing, hospital outpatient emergency buildings and ward buildings, teaching buildings, and kindergartens is mentioned in the prohibition range of the glass curtain wall [24]. In the interference light limitation, Beijing has proposed strict control of interference light from night lighting facilities on houses, apartments, hospital wards, etc. The maximum vertical illumination on the windows of residences and hospital wards is given, and the maximum light intensity of the illuminant is directly seen from the inside [25]. Table 10 shows the maximum vertical illumination on windows in Shanghai. Table 11 shows the maximum light intensity limit on windows in Shanghai. Table 12 shows the vertical illumination limit on windows and light intensity of the illuminator on windows in Beijing (light intensity is the amount of visible power per unit solid angle, measured in candelas (cd, or lm/sr) [17]).

Table 10. The maximum vertical illuminance on the surface of a residential building window in Shanghai.

Time	Environment Zones			
	E1	**E2**	**E3**	**E4**
Evening	2 lx	5 lx	10 lx	25 lx
After 23 o'clock	0.5 lx	1 lx	5 lx	10 lx
The latest time to deactivate decorative landscape lighting according to the Shanghai municipal lighting management department is 23 o'clock.				

Table 11. The maximum light intensity limit for a luminaire in a residential building window in Shanghai.

Time	Environment Zones			
	E1	**E2**	**E3**	**E4**
Evening	2500 cd	7500 cd	10,000 cd	25,000 cd
After 23 o'clock	10 cd	500 cd	1000 cd	2500 cd

Table 12. Interference light control in residential rooms and hospital ward windows in Beijing.

	Residential Areas not Adjacent to Streets		Residential Areas Adjacent to Streets	
	Before 23 o'clock	**After 23 o'clock**	**Before 23 o'clock**	**After 23 o'clock**
Vertical illumination on windows	<10 lx	<2 lx	<25 lx	<5 lx
Direct view of the light intensity of the illuminator	<2500 cd	<1000 cd	<7500 cd	<2500 cd

4.5.5. Public Area Lighting

In the lighting restrictions of public activity areas, Shanghai provides lighting requirements for public activity areas and sets illumination standards for grasslands, gardens, platforms, and children's playgrounds, where minimum illumination levels, illumination uniformity, and minimum vertical illumination are proposed [23]. Guangzhou has imposed time limits on nighttime lighting in public areas. It is prohibited to have lighting in public areas from 22:00 to 6:00 in the evening and when it affects the normal rest of the surrounding residents. The luminaires and upward light output ratio (ULOR) of the night illumination of the square should conform to the urban nighttime lighting design specifications and must not cause glare or light environmental effects on pedestrians or motor vehicle drivers [24]. Tianjin and Beijing have not imposed lighting restrictions on public areas. Table 13 shows the minimum illumination limit, illuminance uniformity, and minimum vertical illumination for public areas in shanghai.

Table 13. Lighting requirements for public areas in Shanghai.

Zones	Minimum Illumination Level (lx)	Illuminance Uniformity (E min/E max)	Minimum Vertical Illumination (lx)
Lawn	2	1:6	2
Garden	5	1:6	3
Playground	10	1:6	4

Note: E min refers to the vertical illumination in the direction of observation.

4.5.6. Commercial Center Lighting

Commercial areas are high-brightness areas. The average illuminance level of an entire shopping center (including pedestrian streets) and a square floor in Shanghai is no less than 20lx, and the uniformity (Emin/Eav) is 0.1–0.3. The vertical illumination at 1.5 m above the ground facing the viewing direction should be greater than 16 lx of uniformity (Emin/Eav) ≥ 0.2 [23]. Article 34 of the draft for comments in Guangzhou refers to the timing of signage lighting in stylistic and commercial places. The residential community and surrounding cultural and commercial establishments shall be provided with advertisements and signs that do not have outdoor lighting functions. If the surrounding interference light exceeds the technical requirements and causes complaints from residents, the city management comprehensive law enforcement department shall enforce the relevant regulations. Businesses should deactivate ads, logos, and signboard lighting at night before 23:30. This article only regulates the lighting time of style and commercial venues, which fully reduces residents' complaints and the problem of urban light pollution [24]. No such relevant regulations and restrictions exist in Beijing and Tianjin.

4.5.7. Administrative Office Lighting

Administrative office areas belong to medium-brightness areas. The ambient lighting in the prescribed area of Shanghai should maintain the outdoor lighting level until the turn on/off light period and then reduce the minimum requirements to ensure pedestrians' safety and security. After public illumination is reduced, the average vertical illumination on a floor of an office building or industrial plant floor should be less than 4lx, and the average illumination on the surrounding road should be no more than 2lx. However, this regulation only addresses safety-related issues and does not address lighting restrictions or light pollution restrictions [23]. Other Chinese cities have no laws addressing lighting related to administrative offices.

4.5.8. Building Exterior Lighting

In the architectural exterior lighting restrictions, Shanghai aims to determine the scale and intensity of floodlighting, the scale relationship between objects of floodlighting and the surrounding environment, and the viewing range. The direction of light projection of the building's exterior lighting and the luminaires used should prevent glare and minimize light trespass. If the building facade is illuminated by floodlights, the direct luminous flux outside the illuminated surface should not exceed 25% of the total luminous flux of the fixture. Hospitals and residential buildings should not use floodlighting in outdoor spaces. Shanghai laws also provide maximum limit values for building surface brightness [23]. In addition, Guangzhou City has proposed nighttime lighting requirements for buildings, glass curtain wall buildings, and night illumination of the main part of buildings, hospitals, residential buildings, etc., with a surface material reflectance less than 0.2; floodlighting shall not be used. Floodlight luminaires shall not project the beam into the interior of the illuminated building. The spilled light beyond the illuminated area shall not exceed the design specifications of the urban nightscape lighting. The main part of buildings including hotels should be encouraged to adopt the illuminating night illumination method of façade floodlighting and to use internal light-transmissive lighting. The use of internal light-transmitting illumination should limit internal light transmission

and ambient light brightness and color to prevent the light from being affected by the internal light [24]. Beijing offers a brightness limit for building facades [25]. No regulations have been enacted in Tianjin. Tables 14 and 15 show the maximum surface brightness of buildings in Shanghai and Beijing.

Table 14. Maximum surface brightness of buildings in Shanghai.

Environment Zones	E1	E2	E3	E4
Maximum brightness on the surface of a building	0 cd/m^2	10 cd/m^2	60 cd/m^2	150 cd/m^2

Table 15. Maximum surface brightness of buildings in Beijing.

Environment Zones	Low Light Environment	Moderate Light Environment	High Light Environment
Maximum brightness on the surface of a building	<10 cd/m^2	<20 cd/m^2	<45 cd/m^2

4.5.9. Greenbelt and Square Landscape Lighting

In green space and square landscape lighting, Shanghai proposed that a tree be irradiated from 3m to 5m, and a floodlight should be installed on the ground and not produce glare. Flowers should be illuminated from top to bottom, light sources containing wavelengths harmful to trees should be strictly limited around trees, and lighting time and intensity should be controlled for general trees. Lighting facilities should not be entangled or installed on trees for long periods of time and should not affect the growth of plants [23]. Guangzhou City proposed that glass curtain walls are forbidden to be installed in natural dark areas, such as nature reserves and forest parks [24]. Other regulations have not been raised. Similarly, Beijing and Tianjin did not propose relevant regulations.

4.5.10. Lighting of Rivers, Ponds, Fountains, and Other Water Bodies

Since rivers, bridges, ponds, fountains, and other bodies of water are commonly illuminated, Shanghai has proposed regulations for lighting rivers with seasonal or periodic water level changes. Lighting equipment on river banks and bridges must consider the effects of changes in the water level. Bridge floodlighting illuminates the upper and lower sides of the bridge deck. When the surface of the static water is arranged, the glare of the light source of the lightbox should be avoided [23]. Other cities have not yet established any such regulations.

4.5.11. Advertising, Signboards, Display Signage, and Logo Lighting

In advertising, signboards, display screens, and logo lighting, Shanghai limits self-illuminating billboards and surface brightness of signboards and displays and also gives a maximum for functional lighting of urban commercial areas, public event areas, stadiums, and other places. The maximum vertical illuminance value of nighttime lights (including self-illuminating advertisements, signboards, displays, signs, etc.) relative to the obstacle light is generated at the observer's eyes [23]. Guangzhou City proposed that, to set up a large electronic display of neon light-illuminating materials and video outdoor advertising facilities, its location, brightness, and operating time should meet the technical specifications and light environment control requirements of the area [24]. There are no relevant regulations in Beijing and Tianjin. Tables 16 and 17 show the self-illuminating billboard, signboards, display screen, and logo surface brightness maximum limit and maximum vertical illumination of the interference light produced in Shanghai.

Table 16. Self-illuminating billboard, signboards, display screen, and logo surface brightness maximum limit value in Shanghai.

Environment Zones	E2	E3	E4
Self-illuminating billboard, signboards, display screen, and logo surface brightness maximum limit value	200 cd/m^2	500 cd/m^2	1,000 cd/m^2
According to the regulations on the forbidden zone proposed in the layout plan of the outdoor advertising facilities in Shanghai, national parks, nature reserves, and observatories are prohibited areas.			

Table 17. The maximum vertical illumination of the interference light produced by self-illuminating billboards, signboards, display screens, and logos at the height of the human eye in Shanghai.

Environment Zones	E1	E2	E3	E4
Additional vertical illumination at eye level of 1.5m	1 lx	3 lx	8 lx	15 lx
Note: Refers to values other than those generated by the environment.				

4.5.12. Limits and Measurement Methods of Maximum Visible Brightness for Light Emitting Diode (LED) Displays in Public Places

Shanghai has a limit for the maximum visible brightness of outdoor LED displays when the outdoor natural environment illumination is not more than 200lx (when the outdoor natural environment illumination is greater than 200lx, there is no limit to the maximum visible brightness of LED displays).

The maximum visible brightness of the indoor LED display is limited when the screen environment illumination is not more than 400lx (when the ambient illumination of the screen is greater than 400lx, there is no limit to the maximum visible brightness of the LED display).

The selection of test points was proposed in Shanghai using the measurement method. The test should be performed at multiple points suitable for viewing the display screen or possibly affecting the crowd. The measurement results can be listed or considered as the maximum value.

The measurement of natural environment illuminance was applied to the outdoor screen smoothly, and the position with only natural light outside the room was selected. The horizontal illuminance at 1.5 m from the ground was the natural ambient illuminance of the test site.

The illumination of the ambient environment of the screen was determined by selecting at least four points as close as possible to the periphery of the display screen, measuring the incident illuminance in the normal direction of the screen at each point, and calculating the arithmetic mean to illuminate the ambient environment around the display screen.

In the measurement step, there are four steps: 1. Determine that the running status of the LED display and the displayed image signal are the same as when the display is actually running. 2. Measure the relevant ambient illuminance with an illuminometer and record the ambient illuminance conditions. 3. In the visible range of the LED display audience, select the test point where you may observe the peak brightness of the screen, the position of the test point is extremely high, and the LED screen is tested at this position. 4. In a certain period of time, use the luminance meter to capture the peak brightness on the LED display and record it as L (i). In the measurement of brightness, the optical probe should not collect less than 16 adjacent pixels. You can select N test points and repeat the steps noted above. The luminance peak value L (i) of one test point is obtained (i: 1 ~ N). Then, the maximum visible brightness of the LED display is the maximum value Lmax among the brightness peaks of the N test points [27].

Guangzhou utilizes several outdoor advertising and signboard management methods. In the fourth paragraph of Article 12, lighting of advertisements and signs in the form of LED outdoor electronic displays is prohibited from 22:30 to 7:30 the next day. Similarly, Guangzhou light radiation environment management specifications (draft for comment) Article 33 proposes that outdoor advertising and signs set up in the form of LED outdoor electronic displays are prohibited from 22:30 to 7:30 at night, except airport and train display screens that announce information on stations, bus stops, etc. Guangzhou City only controls the timing of lighting, and there is no objective limit to lighting [28]. Tianjin and

Beijing have not put any regulations on LEDs. Tables 18 and 19 show the maximum visible brightness of outdoor and indoor LED displays in Shanghai.

Table 18. Limit of the maximum visible brightness of outdoor LED displays in Shanghai.

NO	Area S (m^2)	Limit of the Maximum Visible Brightness		
		Commercial Center Area	Public Area	Residential Area
1	S ≦ 10	800 cd/m^2	600 cd/m^2	300 cd/m^2
2	S < 10	600 cd/m^2	400 cd/m^2	300 cd/m^2

Table 19. Limit of the maximum visible brightness of indoor light emitting diode (LED) displays in Shanghai.

NO	Area S (m^2)	Limit of the Maximum Visible Brightness		
		Commercial Center Area	Public Area	Residential Area
1	S ≦ 10	1,200 cd/m^2	800 cd/m^2	400 cd/m^2
2	S < 10	960 cd/m^2	640 cd/m^2	320 cd/m^2

4.5.13. Contravention Fines

In the Guangzhou light radiation environmental management specifications (draft for comment), if a glass curtain wall is installed in a prohibited place, a fine of no more than 50,000 yuan (7450 USD) will be imposed. If a glass curtain wall material that does not meet the requirements is used, a fine of no more than 30,000 yuan (4470 USD) shall be imposed. If light source, lighting, and lighting methods that do not meet the requirements are used, a fine of no more than 30,000 yuan (4470 USD) shall be imposed. If municipal road tunnel lighting adopts a light source that does not meet the requirements for lighting mode, the dimming design does not meet the requirements of the specifications, or if the luminaire is not turned off at night, a fine of no more than 30,000 yuan (4470 USD) shall be imposed. If city night lighting facilities are not closed in accordance with the prescribed time, a fine of no more than 50,000 yuan (7450 USD) shall be imposed. The above noted penalties are imposed by the construction administrative department. Article 37 proposes that, if the existing glass curtain wall is ordered to be rebuilt within a time limit and the builder refuses or does not complete the task by the time limit, a fine of no more than 50,000 yuan (7450 USD) will be imposed. This article details the punishments to be imposed by the administrative department of land and resources. Article 39: The penalties imposed by the administrative departments of forestry and principles shall be as follows. First, those who install glass curtain walls in buildings in natural dark areas, such as nature reserves and forest parks, shall be fined no more than 50,000 yuan (7450 USD). Second, those who use night scene lighting, lighting, and lighting of outdoor advertising in dark environment areas shall be fined less than 50,000 yuan (7450 USD) [24]. Only Guangzhou has put forward relevant contravention fines.

5. Comparative Analysis of the Seoul and Chinese Light Pollution Ordinances

As indicated in Table 7; Table 8, the lighting divisions are listed separately according to the CIE standard for Shanghai and Beijing. Since there is no dark–light area in the Beijing area, it does not appear on the standard. Guangzhou City has proposed to organize the development of light environment control areas with relevant departments. However, the provision does not give a specific division, which cannot constitute legal benefits. By comparison, Shanghai is the most comprehensive in the lighting division, although Seoul City and Shanghai are almost the same. Therefore, China has followed international standards in the lighting division.

In the lighting division, Shanghai has mentioned the maximum value of the upward light output ratio. In road lighting design, people often underestimate the increase in light pollution caused by the

direct upward discharge of lamps [29]. The upward light output ratio is often used to compare these emissions. Cinzano and Diaz Castro [30] suggested that the direction of light emission is important for determining the amount of light scattered in the atmosphere and the size of the contaminated area. The spread of light pollution is also related to the direction of the launch. Therefore, decreasing the light output ratio is necessary to curb light pollution.

Furthermore, in residential lighting, Shanghai not only gives the maximum vertical illumination of windows, but also gives the standard of lighting intensity for residential areas. Falchi et al. [31] reported that human exposure to light at night (LAN) reduces the production and secretion of pineal melatonin (MLT). Restraining the production of MLT requires two optical variables: Light intensity and wavelength. Therefore, an increase in light intensity may inhibit the production of MLT and have serious negative impacts on health. Light intensity has a negative impact not only on humans, but also on animals. Anika et al. [32] experimented with perch, using aquariums to simulate four different light intensities for 14 days of observation. Through analysis, it was found that nighttime melatonin was inhibited as light intensity increased.

Meanwhile, Shanghai has only proposed minimum horizontal illuminance and vertical illuminance, but has not given a maximum limit for public area lighting. It has been documented that the main factor of the human sensation of glare is high light source brightness [33–35], and the overall brightness in human vision is closely related to the feeling of glare [36]. Therefore, Shanghai has not paid much attention to the possibility of glare in public areas. The specification only mentions that the lighting in public activity areas should create a bright, clear, and friendly atmosphere. Therefore, its regulations do not constitute a standard for light pollution. In contrast, Guangzhou has clearly defined a design standard for public areas and proposed night lighting that effectively control the glare and light environment affecting pedestrians and motor vehicles.

However, although the specification mentions that lighting facilities need to meet design standards, the standards are subtly explained. In practical applications, there is a tendency for formalism and lack of maneuverability, and prevention and control of light pollution are not achieved. In addition, since commercial center lighting areas and administrative office lighting areas are in high-brightness areas, neither Shanghai nor Tianjin have given relevant restrictions on light pollution, and no specific solutions have been given. However, Guangzhou has pointed out that specific departments should solve the relevant complaints. As mentioned above in how to resolve related disputes, if there are no clear relevant standards, it is difficult for government departments to convince other departments, which brings difficulties to management. In addition, in green space and plaza landscape lighting, to avoid unnatural plant growth and generation of glare, Shanghai limits the distance, location, and time of illumination. Intense light pollution at night may disturb the growth of plants [37]. More and more artificial lighting is used to grow plants in greenhouses, causing light pollution [38]. Most creatures tend to be active at night, but, unfortunately, night lighting is also the most important for humans. Excessive artificial lighting not only interferes with the growth of plants, but also causes serious damage to the health of birds, fish, insects, and even humans [39–42]. Therefore, a consideration of the effects on the human ecological environment is crucial. Although Shanghai has relatively curbed the production of light pollution, it has not proposed relevant standards. Similarly, Guangzhou has only limited the use of glass curtain walls, and Tianjin has only mentioned the prevention of glare.

In contrast, the emergence of floodlights has increased artistic beauty due to the emergence of modern buildings. Most floodlighting starts at the bottom of the object [43]. This means that most of the luminous flux is directed to the sky, causing it to miss objects, especially in projects where inappropriate design or poor-quality fixtures are often used. This will lead to a huge loss of energy and light pollution [44]. Krzysztof [45] said that the ratio of luminous flux of floodlighting needs to be determined on the surface of the object and named this measure the floodlighting utilization factor, which is part of the luminous flux of an object. Therefore, the portion of light not directed at the object is the loss of luminous flux. He used formulas and computer simulations to calculate the floodlighting utilization factor and loss of luminous flux at different angles of illumination. Thus, the angle, the loss

of luminous flux, and the floodlighting utilization factor can be used to determine the production of light pollution and the loss of energy. In Shanghai, clear regulations and standards are given for the floodlighting utilization factor and loss of luminous flux, which states that the luminous flux outside the building surface must not exceed 25% of the total luminous flux, and it gives the maximum limit of the brightness of a building surface. All in all, this measure can relatively reduce the occurrence of light pollution.

In advertising lighting, both the Illuminating Engineering Society of North America (IESNA) [46] and the International Commission on Illumination (CIE) [22] recommend limiting outdoor lighting. Although both give attention to this issue, the limits given by the two are different. IESNA gives the limitation of surface brightness, while the CIE150 report gives the limits of the brightness and vertical illumination of the sign. We all know that the surface brightness limit term adjusts the brightness of a single sign, while vertical illuminations are used to prevent outdoor light from entering a room [11]. Although the latter is more suitable for evaluating the light intrusion status of advertising signs, Shanghai has not ignored the limitation of surface brightness and provides two limits.

In advertising lighting, Shanghai not only gives the limit values for surface brightness and vertical illumination, but also limits the LED display. In recent years, with the widespread use of LED displays in China, the LED advertising screens arranged in the city have seriously affected the normal life of residents. However, current international standards cannot be fully applied to the pollution status of Chinese cities. Therefore, research on LED display pollution in various cities in China is urgent [47]. LED displays consume 12 times more energy per day than common signage lighting and severely increase the vertical illumination of the building façades in commercial areas, greatly increasing light intrusion [48]. In addition, high-brightness dynamic picture LED displays create visual interference for drivers [49].

In summary, Shanghai has the most comprehensive limits on light pollution, followed by Guangzhou. However, the specifications of Guangzhou City are only drafts and do not have legal benefits. On the official website of the Guangzhou Municipal Government, to communicate with the people in a timely manner and solve problems, the government has a leadership mailbox. Some citizens have asked whether the regulations on environmental radiation management in Guangzhou have been officially promulgated and implemented. What is the basis? The government replied that it does not specifically regulate light pollution. It gives the Guangzhou building glass curtain wall management measures and the Guangzhou outdoor advertising and signboard management methods as measures related to light pollution [50]. However, in these two regulations, only the relevant restrictions of LED display screens and glass curtain walls on second floors are specified in the relevant buildings [28,51]. Finally, it can easily be seen from Table 6 that Beijing and Tianjin have not paid special attention to the relevant regulations on light pollution. Therefore, the relevant specifications given by Shanghai for the light pollution problem are the most comprehensive.

On the other hand, Seoul gives limits not only for decorative lighting, but also for lighting in the overall space. China's local laws and regulations are mainly reflected in one aspect, such as landscape lighting or decorative lighting, which lacks operability. On the contrary, this single mode has given some inspiration to Seoul, such as the ULOR proposed by Shanghai, the intensity of lighting, the brightness of building surfaces, the surface brightness of advertising signs, and the hard regulations related to light pollution. Seoul can improve the effectiveness of its laws and regulations according to the actual situation and the above noted provisions.

6. Recommendations

The authors believe that improving China's light pollution laws and regulations requires improvements to the legislative model, such as special legislation on light pollution. Depending on the actual situation of each city, light pollution impact assessment should be performed according to clear criteria. For example, Seoul proposes that the mayor should strive to maintain the Korean industrial standard street lighting as the standard for light pollution environmental impact assessment and can

seek expert advice accordingly. In addition, special department supervision is needed. For example, Seoul clearly stipulates that the mayor should formulate and implement policies to prevent light pollution and establish a light pollution committee. There should be clear accountability and incentive mechanisms, such as in Seoul, and the mayor may choose to reward those who contribute to the prevention of light pollution [16].

Furthermore, in the actual control, data analysis is needed, and the night sky brightness of different cities is collected to conduct a comparative analysis, and the results are obtained and then controlled point-to-point. For example, Wei Jiang et al. [52] used the Luojia 1–01 satellite to analyze and compare the night sky brightness with the brightness of different degrees in Wuhan, Seoul, Haifa and Mexico.

On the other hand, in future research of laws and regulations, the brightness of the night sky should be compared before and after the data in a range of years, so that the practicability of the current rules can be confirmed—for example, Wei Jiang et al. [53] used the Defense Meteorological Satellite Program Operational Linescan System (DMSP/OLS) for data collection from 1992 to 2012 in assessing light pollution in China based on nighttime light imagery and analyzed the degree of light pollution in various regions of China. It was concluded that China's light pollution has significantly expanded in provincial capital cities in the past 21 years. Therefore, by analyzing this, we can see that the degree of light pollution is on the rise when no relevant light pollution regulations are proposed. In the future, it is necessary to continue collecting proper data to compare and analyze the practicability of current rules on light pollution.

At the same time, in future research, the ecosystem needs to be paid attention to in light pollution. We can also conduct data comparison analysis. For example, Jonathan et al. [54] used DMSP/OLS in combination with GLC2000 to collect nighttime lights from 1992 to 2012 and evaluated the latest changes in nighttime artificial illumination for 43 global ecosystem types. The results indicated that the Mediterranean climate–ecosystem has experienced an enormous increase in exposure and that all terrestrial ecosystem types have experienced a certain degree of artificial light exposure and that this exposure is increasing. Through the analysis of the ecosystem, the relevant laws and regulations can be strengthened in the future.

In the era of big data, we not only need to use data collection but also need to listen to the opinions of the public—for example, the public's views on light pollution and its impact on the environment. Lyytimaki et al. [55] investigated the public's views on light pollution as an environmental problem using a questionnaire survey. Of the 2053 responses to the study, 84.6% said light pollution had spread to all areas. A total of 82.9 per cent of the respondents said it was essential to be dark. Various light pollution sources were found in the problem of light pollution sources. The most commonly mentioned sources were street lamps, courtyard lamps, commercial lights, and outdoor decorative lights. Therefore, the author believes that only by combining a questionnaire survey, interviews, and DMSP/OLS data collection, etc. can the occurrence of light pollution be effectively controlled, and the effectiveness of laws and regulations be improved in the future.

7. Conclusions

In the present study, we collected information pertaining to the control of local and national light pollution in Korea and four Chinese cities. We found that although both countries have relatively robust light pollution control policies, there are still many problems that need to be addressed. For instance, local light pollution laws in China seem too simple and lack specificity for a complex issue such as light pollution. For example, many local light pollution policies in China do not provide lighting standards for decorative and advertisement lighting, and yet these two forms of artificial lighting are major contributors to local light pollution. The issue of generalization is also seen in light pollution policies in Korea; for example, the lighting limits provided for advertisement lighting in the Korean "Light Pollution Prevention Law" are intended to control luminance levels emitted by a single signboard instead of the net luminance radiated by all the signboards on a building façade. As such, given that the two countries share a similar socio-economic background, they can learn from each other's specific

approaches to tackling light pollution. The current study, therefore, provides the basis for discussing this exchange of ideas between Korea and China on the issue of light pollution control and policy.

Author Contributions: Conceptualization, methodology, resources, compare analysis, W.G., J.N. and K.G.; investigation, writing—original draft preparation W.G.; writing—review and editing, supervision, J.N. and K.G.

Conflicts of Interest: The authors declare no conflict of interest.

References and Notes

1. Rybnikova, N.A.; Haim, A.; Portnov, B.A. Is prostate cancer incidence worldwide linked to artificial light at night exposures? Review of earlier findings and analysis of current trends. *Arch. Environ. Occup. Health* **2017**, *72*, 111–122. [CrossRef] [PubMed]
2. James, P.; Bertrand, K.A.; Hart, J.E.; Schernhammer, E.S.; Tamimi, R.M.; Laden, F. Outdoor light at night and breast cancer incidence in the nurses' health study II. *Environ. Health Perspect.* **2017**, *125*, 087010. [CrossRef] [PubMed]
3. Hu, C.; Jia, W. Linking MTNR1B Variants to Diabetes: The Role of Circadian Rhythms. *Diabetes* **2016**, *65*, 1490–1492. [CrossRef] [PubMed]
4. Weinert, D.; Waterhouse, J. *Interpreting Circadian Rhythms, in Biological Timekeeping: Clocks, Rhythms and Behaviour*; Springer: Berlin, Germany, 2017; pp. 23–45.
5. Liu, M.; Zhang, B.G.; Li, W.S.; Guo, X.W.; Pan, X.H. Measurement and distribution of urban light pollution as day changes to night. *Lighting Res. Technol.* **2018**, *50*, 616–630. [CrossRef]
6. Kyba, C.C.M.; Kuester, T.; De Miguel, A.S.; Baugh, K.; Jechow, A.; Hölker, F.; Bennie, J.; Elvidge, C.D.; Gaston, K.J.; Guanter, L. Artificially lit surface of Earth at night increasing in radiance and extent. *Sci. Adv.* **2017**, *3*, e1701528. [CrossRef] [PubMed]
7. Gaston, K.J.; Davies, T.W.; Bennie, J.; Hopkins, J. REVIEW: Reducing the ecological consequences of night-time light pollution: Options and developments. *J. Appl. Ecol.* **2012**, *49*, 1256–1266. [CrossRef] [PubMed]
8. Ko, T.K.; Kim, I.T.; Choi, A.S.; Sung, M.K. Quantitative assessment methods for determining luminous environmental zones in Korea. *Lighting Res. Technol.* **2016**, *48*, 307–322. [CrossRef]
9. Morgan-Taylor, M. *Regulating Light Pollution in Europe: Legal Challenges and Ways Forward*; Routledge: Abingdon, UK, 2015.
10. Cha, J.; Lee, J.; Lee, W.; Jung, J.; Lee, K.; Han, J.; Gu, J. Policy and status of light pollution management in Korea. *Light. Res. Technol.* **2014**, *46*, 78–88. [CrossRef]
11. Ho, C.; Lin, H. Analysis of and control policies for light pollution from advertising signs in Taiwan. *Lighting Res. Technol.* **2015**, *47*, 931–944. [CrossRef]
12. Taylor, M.M. Light pollution and nuisance: The enforcement guidance for light as a statutory nuisance. *JPL* **2006**, *8*, 1114–1127.
13. Zitelli, V.; Di Sora, M.; Ferrini, F. Local and national regulations on light pollution in Italy. In *Symposium-International Astronomical Union*; Cambridge University Press: Cambridge, UK, 2001.
14. Ngarambe, J.; Kim, G. Sustainable Lighting Policies: The Contribution of Advertisement and Decorative Lighting to Local Light Pollution in Seoul, South Korea. *Sustainability* **2018**, *10*, 1007. [CrossRef]
15. Cook, T.D.; Leviton, L.C. Reviewing the literature: A comparison of traditional methods with meta-analysis 1. *J. Personal.* **1980**, *4*, 449–472. [CrossRef]
16. Seoul Metropolitan Government Ordinance on the Prevention of Light Pollution and Management of Formation of Good Light. Available online: http://legal.seoul.go.kr/legal/english/front/page/law.html?pAct=lawView&pPromNo=1442 (accessed on 24 January 2018).
17. Taylor, A.E.F. *Illumination Fundamentals*; Lighting Research Center: Troy, New York, NY, USA, 2000.
18. China, T.N.P.s.C.o.t.P.s.R.o. Constitution of the People's Republic of China. Available online: http://www.npc.gov.cn/englishnpc/Constitution/node_2825.htm (accessed on 14 October 2018).
19. Congress, S.N.P.s. General Principles of the Civil Law of the People's Republic of China. Available online: http://www.npc.gov.cn/englishnpc/Law/2007-12/12/content_1383941.htm (accessed on 13 April 1986).
20. Congress, F.S.o.t.T.N.P.s. Property Law of the People's Republic of China. Available online: http://www.npc.gov.cn/englishnpc/Law/2009-02/20/content_1471118.htm (accessed on 1 October 2007).

21. Environmental Protection Law of the People's Republic of China. Available online: http://www.npc.gov.cn/englishnpc/Law/2007-12/12/content_1383917.htm (accessed on 26 December 1989).
22. l'éclairage, C.i.d. *Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations*; Technical Report; CIE: Vienna, Austria, 2003.
23. Association, S.M.B.O.Q.A.T.S.S.l. *Specifications on Urban Environment (Decoration) Lighting*; Municipal Bureau of Quality and Technical Supervision: Shanghai, China, 2012.
24. Bureau, G.E.P. *Guangzhou Light Radiation Environment Management Specifications (Draft for Comment)*; Legal Office of Guangzhou Municipal People's Government: Shanghai, China, 2014.
25. Beijing Municipal Administration of Quality and Technology Supervision. *Technical Specification of Urban Landscape Lighting*; Beijing Municipal Administration of Quality and Technology Supervision: Beijing, China, 2015.
26. Xingguo, M.h. *Tianjin City Lighting Management Regulations*; Tianjin Municipal People's Government: Tianjin, China, 2012; pp. 2–6.
27. Shanghai Municipal Bureau of Quality and Technical Supervision; Shanghai Information System Quality Technology Association; Shanghai Landscape Affairs Center; Shanghai Sansi Technology CO., L. *Limits and Measure Methods of Maximum Visible Brightness for Public Places Light Emitting Diode (LED) Panels*; Shanghai Municipal Bureau of Quality and Technical Supervision: Shanghai, China, 2013.
28. Jianhua, M.C. *Guangzhou Outdoor Advertising and Signboard Management Methods*; G.m.p.s.: GuangZhou, China, 2014.
29. Cinzano, P. Light pollution by luminaires in roadway lighting. *CIE Div. TC4* **2003**, *21*, 1–8.
30. Falchi, F.; Cinzano, P. Measuring and modelling light pollution. *Mem. Soc. Astron. Ital.* **2000**, *71*, 139–152.
31. Falchi, F.; Cinzano, P.; Elvidge, C.D.; Keith, D.M.; Haim, A. Limiting the impact of light pollution on human health, environment and stellar visibility. *J. Environ. Manag.* **2011**, *92*, 2714–2722. [CrossRef] [PubMed]
32. Brüning, A.; Hölker, F.; Franke, S.; Preuer, T.; Kloas, W. Spotlight on fish: Light pollution affects circadian rhythms of European perch but does not cause stress. *Sci. Total. Environ.* **2015**, *511*, 516–522. [CrossRef] [PubMed]
33. Chauvel, P.; Perraudeau, M. Daylight as a source of visual discomfort-Daylighting Atlas. *Lyon Joule* **1995**, *2*, 17.
34. Collins, J.; Dogniaux, R.; Chauvel, P.; Longmore, J. Glare from windows: Current views of the problem. *Light. Res. Technol.* **1982**, *14*, 31–46.
35. Nazzal, A.; Oki, M. Could Daylight Glare Be Defined Mathematically? *J. Light Vis. Environ.* **2007**, *31*, 44–53. [CrossRef]
36. Osterhaus, W. Discomfort glare from daylight in computer offices: How much do we really know. In Proceedings of the LUX Europa, Reykjavik, Iceland, 18–20 June 2001; pp. 448–456.
37. Briggs, W.R. Physiology of plant responses to artificial lighting. *Ecol. Conseq. Artif. Night Lighting* **2006**, 389–411.
38. Rogge, E.; Dessein, J.; Gulinck, H. Stakeholders perception of attitudes towards major landscape changes held by the public: The case of greenhouse clusters in Flanders. *Land Use Policy* **2011**, *28*, 334–342. [CrossRef]
39. Knight, A.L.; Weiss, M.; Weissling, T. Diurnal patterns of adult activity of four orchard pests (Lepidoptera: Tortricidae) measured by timing trap and actograph. *J. Agric. Entomol.* **1994**, *11*, 125–136.
40. Svensson, M.G.E.; Rydell, J.; Brown, R. Bat Predation and Flight Timing of Winter Moths, Epirrita and Operophtera Species (Lepidoptera, Geometridae). *Oikos* **1999**, *84*, 193. [CrossRef]
41. Jetz, W.; Steffen, J.; Linsenmair, K.E. Effects of light and prey availability on nocturnal, lunar and seasonal activity of tropical nightjars. *Oikos* **2003**, *103*, 627–639. [CrossRef]
42. Moser, J.C.; Reeve, J.D.; Bento, J.M.S.; Della Lucia, T.M.C.; Cameron, R.S.; Heck, N.M.; Bento, J.M.S. Eye size and behaviour of day- and night-flying leafcutting ant alates. *J. Zoöl.* **2004**, *264*, 69–75. [CrossRef]
43. Żagan, W. *Iluminacja Obiektów*; OWPW: Warszawa, Poland, 2003; ISBN 83-7207-360-0.
44. Kubiak, K. About the necessity of break of the stagnation in illumination lighting equipment. *Prz. Elektrotechniczny* **2012**, *88*, 108–114.
45. Skarżyński, K. An attempt at controlling the utilisation factor and light pollution within the context of floodlighting. *Prz. Elektrotechniczny* **2016**, *1*, 180–183. [CrossRef]
46. Illuminating Engineering Society of North—The Lighting Authority; I.R.L. Committee. *IESNA Technical Memorandum on Light Trespass: Research, Results and Recommendations*; Illuminating Engineering Society of North—The Lighting Authority: I.R.L. Committee: New York, NY, USA, 2000.

47. Na, L. *Simulation Study on Typical Colour Light Trespass around Residential Buildings caused by LED Advertising Screens*; Tianjin University: Tianjin, China, 2017.
48. Ho, C.Y.; Lin, H.T.; Huang, K.Y. A Study on Energy Saving and Light Pollution of LED Advertising Signs. In *Applied Mechanics and Materials*; Trans Tech Publications: Zurich, Switzerland, 2012.
49. Farbry, J.; Wochinger, K.; Shafer, T.; Owens, N.; Nedzesky, A. *Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction*; Science Applications International Corporation: Reston: VA, USA, 2001.
50. Guangzhou Light Pollution Law Basis; 2018.
51. Wen, G.H. Guangzhou Building Glass Curtain Wall Management Measures. 2017. Available online: https://www.gz.gov.cn/gzgov/s8263/201706/2de15a795c2a4fcea73de0d25453c98e.shtml (accessed on 23 July 2019).
52. Jiang, W.; He, G.; Long, T.; Guo, H.; Yin, R.; Leng, W.; Liu, H.; Wang, G. Potentiality of Using Luojia 1-01 Nighttime Light Imagery to Investigate Artificial Light Pollution. *Sensors* **2018**, *18*, 2900. [CrossRef]
53. Jiang, W.; He, G.; Long, T.; Wang, C.; Ni, Y.; Ma, R. Assessing Light Pollution in China Based on Nighttime Light Imagery. *Remote. Sens.* **2017**, *9*, 135. [CrossRef]
54. Bennie, J.; Duffy, J.P.; Davies, T.W.; Correa-Cano, M.E.; Gaston, K.J. Global Trends in Exposure to Light Pollution in Natural Terrestrial Ecosystems. *Remote. Sens.* **2015**, *7*, 2715–2730. [CrossRef]
55. Lyytimäki, J.; Rinne, J. Voices for the darkness: Online survey on public perceptions on light pollution as an environmental problem. *J. Integr. Environ. Sci.* **2013**, *10*, 127–139. [CrossRef]