Visual and Non-visual Impacts of Commercial Self-luminous Signboards in Residential Areas in China

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Light Pollution in China

Light pollution is the fifth largest pollution after air pollution, water pollution, solid waste pollution and noise pollution, which includes light trespass, over-illumination, glare, light clutter and skyglow. Light pollution can affect both ecological environments and human health, and has become a worldwide problem.



@ Falchi et al., 2016

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Light Pollution in China

Although the Urban Lighting Projects (ULP) has played an important role in shaping cities' nighttime landscape, excessively bright lighting environments at night interfere with the advancement of astronomical research, affect the growth of animals and plants, reduces the quality of residents' sleep as well as increase their risk of having cancer. Characteristics of light pollution: physical pollution, locality, no residue and relativity.



Shang Hai



Shen Zhen



Mixed Commercial-Residential Buildings



Nan Jing



Zheng Zhou





Wu Han



Qing Dao

- Mixed commercial and residential buildings (stores on the first floor and residence on the upper floors) are widely used in China. The close relationships between business and residents provides residents with convenience and light pollution in their daily life;
- The signboards of Nanjing shops have the characteristics of different colors (spectral compositions), relatively standardized designs (store names), and large luminance ranges (photopic & circadian aspects).

Four Signboard Types



T1: Neon-based profile



T1: Neon-based billboard



T2: LED-based profile



T2: LED-based billboard



T3: Internal lightbox



T3: External floodlight



T4: Mixed lighting systems



T4: Mixed lighting systems







Projection signboard

Surface signboard

State of the Art

• Ngarambe et al. found that 30% of commercial boards and 70% of decoration lights in Seoul had light pollution (Ngarambe et al., 2018).

• Cha et al. systematically sorted out the "Light Pollution Prevention and Control Law", measured the vertical illuminance of 90 windows, and found that 26% of the measured data exceeded the design criteria, 45% of the average luminance values of building facades exceeded the design criteria, and 36% of the signboards exceeded the design criteria (Cha et al., 2014).

• Chen et al. found that 47% of measured signboard in Shanghai and 86% of measured signboard in Hongkong presented great circadian stimulus over 0.05 (Chen, 2019).

• Ho and Lin evaluated shop signboards in Taiwan using measurement and simulation, and found that oversized signboards, high densities, and inappropriate installation were the main reason for signboard light pollution (The errors between simulation and measurement are 16.1% and 16.6% along two sides without considering light spectral compositions.) (Ho and Lin, 2015).

• Guanglei et al. compared the light pollution control standards in South Korea between those in China and pointed out the simplicity and generalization of these standards. Light pollution policies in China lack standards for decorative lighting and advertising lighting; while South Korea's light pollution policies aim to control the level of luminance emitted by a single signboard rather than the net luminance emitted by all signs on a building's facade (Guanglei, 2019).

To sum up, the light pollution problem of shop signboards is an Asian wide problem. There are limited studies concerning visual and non-visual impacts of signboards. Moreover, studies that use simulation methods could be further explored.



Associated Codes and Regulations

Code name	Zone	Maxin sel	Maximum permitted average values of self-luminous signboards (cd/m²)				
		(0, 0.5] m ²	(0.5, 2] m ²	(2, 10] m ²	(10, ∞) m²		
Code for lighting design of urban nightscape (JGJ/T163-2021) Tianjin technical standard for urban nightscape lighting (DB/T29-71-2021)	E3	800	600	450	300		
Guangzhou code for outdoor billboard and signboard designs Wuhan code for outdoor billboard and signboard designs	Residential areas	100	80	60	40		
Shenzhen technical standard of urban landscape lighting engineering (SJG 105-2021)	E3	800					
Shanghai code for urban lighting environment (decoration)	E3	500					

- \bullet CIE, IESNA-DSA and BSI all restrict 800 cd/m² as the maximum allowable value for E3;
- Different provinces and cities in China have different regulations of signboard luminance thresholds as well as the factors upon which these regulations are established on, such as self-luminous areas and installation height;
- The maximum allowable illuminance on the surface of exterior windows is not convenient for designers to quickly apply in practical projects;

	Installation	Maximum	Installation	Maximum
	position	permitted average	position	permitted average
		luminance (cd/m ²)		luminance (cd/m ²)
Chongqing technical standards for outdoor billboards Qingdao technical standards for outdoor billboards Tianjin technical	Billboard and signboards on shopping malls	250-500	Commercial billboards and gas station light boxes	700-1000
standards for outdoor billboards	Low luminous locations with dark billboard background	450-700	High-rise buildings and downtown areas	1000-1400
\leftrightarrow	Billboards•and•signboar	ds↩	Self-luminous-	Self-luminous-
			area <2 m² ⋅ (lx) ←	area ⊳8 m²- (lx)⇔
Qingdao technical standards for outdoor	Billboards- and- signboar sidewalks-(below-10m)↔	rds· along· roads· and·	200~400	200∼600€
billboards⇔ Jiangsu∙technical•	Billboards∙ and∙ signboan sidewalks•(height•10m•~	rds- along- roads- and- [•] ·40m)←	< ¹	300~1000€
standards for outdoor billboards ↩	Billboards- and- signboar sidewalks-(height-40m-~	rds· along· roads· and· ·50m)€ ²	<	400~1200€∃

• Currently, Chinese codes and standards associated with signboards lack circadian illuminance/luminance thresholds from the colour and spectral perspectives.



• Propose and verify a method that integrates measurement and simulation for selfluminous lightbox signboards;

• Evaluate the lighting quality within mixed residential areas in Nanjing at night from both visual and non-visual aspects.



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Research Flow





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Method - Field Measurement

Luminance & SPD measure



Use a portable spectroradiometer (SRC-2) to measure both luminance and spectral composition of each signboard one hour after sunset. Two to five points were measured for each signboard.

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	6 优鲜果园022023_0 7 优鲜果园032023_0	15_1 875.364 1.696(3 15_1 4.098 0.017(3	80-780 0.3366 0.6293 80-780 0.3708 0.4002	0.1363 0.5733 0.1363 0 0.2101 0.5101 0.2101 0	1. 3822 1. 62 146. 8 (C7 1. 3401 1. 67 14. 8 (C78	5471 536 4405 754	68.5 554.9 90. 2.6 571.2 31.	8 0.09519 0.9 -2 4 0.01357 76.8 71	20 77
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8	12 南湖洋市042023_0	15_1 27. 378 0. 140 (3 27. 378 0. 143 (3	80-780 0.502 0.3044	0.3555 0.485 0.3555 0	0. 93 78. 3 (C78 1. 3233 0. 99 76. 1 (C78	1512 620	73.4 700 4	2 0.03706 63.2 90	80
	13 东北水饺012023_0 14 东北水饺022023_0	15_1 77.45 0.520 (3 15_1 100.659 0.663 (3	80-780 0.6862 0.294 80-780 0.691 0.2944	0.5324 0.5132 0.5324 0 0.5366 0.5144 0.5366 0	0. 3422 0. 16 187. 1 (C7 0. 3429 0. 13 189. 8 (C7	1001 635 1001 635	18. 2 630. 3 94. 18. 1 629. 6 95.	1 -0.08537 53.7 62 6 -0.08941 45.3 49	96 97
	15 东北水投032023_0 16 东北水投042023_0	8.984 0.036 (3 9.417 0.041 (3	80-780 0.406 0.3888 80-780 0.4313 0.3833	0.2383 0.5109 0.2383 0 0.2561 0.512 0.2561 0	. 3406 1. 46 1. 7 (C78 . 3414 1. 33 8. 3 (C78	3425 628 2920 636	21.3 581.8 39. 27.4 586.4 44.	2 -0.00142 86.9 88 5 -0.00776 90.8 98	88 93
1	17 肉夹馍012023_05_ 18 由来情(22022_05	02 553.728 2.126(3 02 446 718 1 724(3	80-780 0.3018 0.2821 80-780 0.3125 0.2821	0.2088 0.4391 0.2088 0	1.2927 2.36 31.2(C78 1.2952 2.28 30.3(C78	8073 450 7031 450	26.7 458.9 16.	8 -0.01665 88.8 92	90
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	22 黑皮砂锅022023_0 23 黑皮砂锅032023 0	15_1 863. 348 3. 141 (3 15_1 126. 558 0. 542 (3	80-780 0.2774 0.2921 80-780 0.4915 0.3516	0.1865 0.4418 0.1865 0 0.3152 0.5074 0.3152 0	1. 2945 2. 64 26. 8 (C78 1. 3383 1. 31 47. 0 (C78	10145 455 1897 616	25.8 481.5 22. 71.5 601 5	5 0.00398 82.2 81 3 -0.02149 65.1 89	88 72
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3	395 6.822-05	394 5.57E-06 395 1.21E-05	394 3.76E-05 395 2.76E-05	394 4.70E-05 395 4.24E-05	394 6. 80E-05 395 6. 32E-05	394 5.97E-05 395 4.65E-05	394 4.44E-05 395 5.11E-05	394 8.43E-05 395 8.67E-05	
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Method - Field Measurement

Illuminance & SPD measure



Illuminance

Spectral Power Density

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序号	仪	器序号 仪器类型	光照度(1x)Rf	f Rg		E(fc)	相阻度(图	n SDCM	白充分级	CIE_x	CIE_y	CIE	_u' 0	IE_v'	相关色温(++	筆值波长64	<这宽(nm)	主波长(nn)t	色纯度(%)	Duv		1	SN : 1	3. 5156e	+001							
	1	1 SFIM	35.156	77	94	3.27E+00	1.05E-0	1 8.6	F500(C78.377_4	0.361	5 0.37	13	0.2147	0.4964	4521	448	24.2	574.4	19.9	0.0035		2	字号	波长(n	a) 絶対	光谱值相)	对光谱值					
	2	1 SFIM	15.814	80	99	1.47E+00	4.99E-0	26.5	F4000C78.377_40	0.373	7 0.36	33	0.226	0.4945	4092	448	26.5	581.8	21.1	-0.0044	0	3			380 1.1	2E-06	0.0015					
1	3	1 SFIM	193.93	57	55	1. S0E+01	4. 50E-0	1 46.4	F3500UT	0.45	0.51	32	0.2212	0.5601	3431	563	112.4	573.4	91	0.0356		4			381 1.3	1E-06	0.0018					
i	- 4	1 SFIM	223.36	57	55	2.08E+01	5.19E-0	1 46.3	F35(0UT	0.456	0.51	33	0.2216	0.5602	3422	565	112.9	573.5	91.3	0.0355	1.7	5		3	382 1.4	9E-06	0.002					
6	5	1 SFIM	203.51	71	74	1.89E+01	4. SSE-0	1 38.7	F35(0UT	0.439	0.49	92	0.2195	0.5512	3548	563	114.3	573.3	79.1	0.0311		6		1	383 1.4	1E-06	0.0019					
	6	1 SFIM	341.13	76	93	3.17E+01	1.06E+0	0 2.4	F650(C78. 377_65	0.319	2 0.3	39	0.1986	0.4745	6114	448	23	496.9	4.5	0.0051	66	7		5	384 9.8	1E-07	0.0013					
5	7	1 SFIM	170.24	80	97	1.58E+01	6.33E-0	1 16.3	8000 OUT	0.276	3 0.27	14	0.1937	0.4282	11941	450	27.1	475.3	25.4	-0.0063	æ	8		3	385 5.5	1E-07	0.0007					
F	8	1 SFIM	177.86	82	103	1.65E+01	6.61E-0	1 15.0	80000UT	0.297	9 0.28	46	0.2048	0.4402	8364	450	26.6	468.4	17.3	-0.0128	w.	9			386 5.8	2E-07	0.0008					
0	9	1 SFIM	308.57	82	113	2.87E+01	1.17E+0	0 23.9	F50COUT	0.346	5 0.30	99	0.2301	0.4629	4730	448	24.6	-517.2	4.8	-0.0234	12	10		3	387 7.6	4E-07	0.001					
1	10	1 SFIM	230.39	82	113	2.14E+01	8.76E-0	1 26.2	F40COUT	0.357	L 0.3	14	0.2359	0.4668	4270	448	24.2	-502.6	7.2	-0.0251	120	11	1	9	388 9.5	-2E-07	0.0013					
2	11	1 SFIM	1479.4	79	110	1.37E+02	5.72E+0	0 24.1	SOOCOUT	0.292	2 0.26	73	0.2079	0.4278	9894	450	26	459.9	21.7	-0.0193		12	10)	389 1.2	.2E-06	0.0016					-
3	12	1 SFIM	2053.4	80	108	1.91E+02	7. S6E+0	0 22.0	SOOCOUT	0.290	4 0.26	84	0.2059	0.4283	10070	450	25.8	463.9	21.9	-0.0175		13	1		390 1.5	.0E-06	0.002					4
4	13	1 SFIM	89.476	86	101	8.32E+00	3.00E-0	18.4	F400COUT	0.3	3 0.36	36	0.2302	0.4956	3910	450	30.8	583.4	23.1	-0.0062		14	1		391 1.5	.3E-06	0.0021					
5	14	1 SFIM	82.158	85	102	7.64E+00	2.79E-0	19.4	F400COUT	0.376	9 0.35	93	0.2299	0.4931	3965	450	30.2	584.5	20.9	-0.0074		15	13	3	392 1.2	.1E-06	0.0016					
6	15	1 SFIM	341.98	71	70	3.18E+01	8.34E-0	1 51.0	F50COUT	0.418	5 0.50	56	0.2032	0.5532	3953	543	130.9	569.8	77.8	0.0408		16	1	1	393 8.9	4E-07	0.0012					
7	16	1 SFIM	382.53	70	69	3.56E+01	9.27E-0	1 51.6	F50COUT	0.417	5 0.50	87	0.2019	0.5536	3981	543	129.9	569.6	78.2	0.0417		17	1	5	394 1.1	2E-06	0.0015					
8	17	1 SFIM	360.84	70	69	3.35E+01	S. 69E-0	1 52.0	F50COUT	0.41	5 0.	51	0.2002	0. 5537	4026	543	129.5	569.2	77.8	0.0427		18	1	5	395 1.5	4E-06	0.0021					
9	18	1 SFIM	51.85	11	120	4. S2E+00	1. SSE-0	1 35.6	F27000T	0.504	0.39	23	0.301	0.527	2061	634	21.6	590.9	69.1	-0.0073		19	1		396 1.9	1E-06	0.0026					
0	19	1 SFIM	37.128	53	153	3.45E+00	1.62E-0	1 77.8	F2700UT	0.541	1 0.34	56	0.3569	0.5128	1505	634	21.1	604.9	66.1	0.0185		20	11	3	397 1.6	.9E-06	0.0023					
	20	1 SFIM	122.23	78	97	1.14E+01	4. 55E-0	1 17.4	100000	0.278	\$ 0.26	90	0.1964	0.4266	11914	451	25.4	473.4	25. 2	-0.0092		21	1	,	398 1.4	78-06	0.002					
2	21	1 SFIM	170.19	77	97	1.58E+01	0. 51E-0	1 22.4	100000	0.273	3 0.25	11	0.1966	0.4192	14299	453	24.8	472	28	-0.0112		22	21		399 1.5	26-06	0.002					
	22	1 SFIM	233.61	81	99	2.17E+01	8. 34E-0	18.1	SUUCEOUT	0.297	a 0.29	51	0.2009	0.4454	8138	451	26.3	474.6	16.1	-0.0077		23	2		400 1.9	02-06	0.0026					
4	23	1 SFIN	644.21	82	103	2. 99E+01	2.312+0	0 12.8	8000001	0.306	0.29	21 00	0.2052	0.4504	1209	450	20.0	4/1	12.7	-0.0096		24	2:		401 2.3	0E-00	0.0032					
6	26	1 OF IN	677.25	82	103	6 20E+01	2.425+0	0 13.4	8000001	0.300	0.29	34	0.2030	0.4499	7275	450	25.2	470.1	12.8	-0.000		25	2.		402 2.3	4E-00	0.0034					
7	20	1 OF IN	249.41	80	101	0. 30ET01	1.29540	0 14 2	SOOCOLT	0.300	0.2	54	0.1096	0.4321	10240	450	25.2	472	19.0	-0.0007		20	21		404 2.7	4D 00	0.0037					
8	20	1 OF IN	492.1	70	100	4 40E+01	1.20010	0 14 0	SOOCOLL	0.201	0.27	74	0 109	0.421	10847	450	20, 1	472.2	66.3	-0.0097		28	21		405 2 1	05-06	0.00012					
9	20	1 SETM	430.04	79	100	4. 00E+01	1.628+0	0 15 1	SOOCOLT	0.203	0.2	17	0.1092	0.4309	10660	450	20	473	63	-0.0095		20		2	406 3.4	OE 00	0.0046					
0	20	1 SETM	264.92	77	100	2.46E+01	1.002+0	0 35 6	SOCOUT	0.250	0.27	71	0.1874	0.3002	57440	430	24.7	473.7	37.7	-0.0065		30	21		407 3.7	(3E-06	0.005					
1		1 OF IN	204.92		22	2.405/01	1.09610	0.00.0	0000001	0.200	0.23		0.1014	0.3992	01440	440	1.91	413.1	31.1	0.0000		30				02 00	0.000					







Method - Data Processing

Models were built in Rhino and then exported to Grasshopper. The simulation results were verified from both visual and non-visual aspects. Concerning the visual aspect, Ladybug & Honeybee (Radiance) were used for simulation. In total, 75 isolated signboards were measured and simulated.

void glow modifier 0 0 4 R G B max_radius

Radiance RGB \longrightarrow CIE XYZ

[R]		[2.5653	-1.1668	-0.3984]	[X]
G	=	-1.0221	1.9783	0.04382	Y
B		l 0.0747	-0.2519	1.1772	LZ





Method - Data Processing

void glow modifier_bluevoid glow modifier_greenvoid glow modifier_red0000004b1b2b3max_radius4g1g2g3max_radius4r1r2r3max_radius4



 $Sum = B_1 * p_{B1} + B_2 * p_{B2} + B_3 * p_B + G_1 * p_{G1} + G_2 * p_{G3} + G_3 * p_{G3} + R_1 * p_{R1} + R_2 * p_{R2} + R_3 * p_{R3}$

$$b_n = \frac{B_n}{\text{Sum}} * \frac{L_{mea}}{179}$$

Lark (Inanici et al., 2015) uses a nine-channel simulation method, which requires both luminance and spectral data as the inputs. Lark calculates circadian illuminance and luminance following the response curve proposed by Lucas et al (2014).

$\leftarrow \neg$	Wavelength↩	Photopic↩	Lucas et al.«
B1←	380-422↩┘	0.0004←⊐	0.0166←⊐
B2←	422-460←⊐	0.0095←⊐	0.1819↩□
B3↩	460-498↩□	0.0522←⊐	0.3973↩
G1↩	498-524↩	0.1288←⊐	0.2468↩□
G2←	524-550←⊐	0.2231↩	0.1204←⊐
G3↩	550-586←⊐	0.3174←	0.0351↩
R1←	586-650↩	0.2521↩	0.0018←
R2←	650-714↩	0.0162←⊐	0←⊐
R3←	714-780↩	0.0002←⊐	0←⊐

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Method - Data Processing



Measured circadian illuminance and luminance values were calculated by using the CIE alpha-opic Toolbox.

$$EML = 72983.25 \int E_{e,\lambda}(\lambda) N_z(\lambda) d\lambda$$

melanopic EDI = $\frac{\int E_{e,\lambda}(\lambda) s_{mel}(\lambda) d\lambda}{K_{mel,V}^{D65}} = \frac{\int E_{e,\lambda}(\lambda) s_{mel}(\lambda) d\lambda}{1.3262 \ mW \cdot lm^{-1}}$
 $\frac{\text{melanopic EDI}}{\text{EML}} = 0.9063 \cdot \frac{\int E_{e,\lambda}(\lambda) s_{mel}(\lambda) d\lambda}{\int E_{e,\lambda}(\lambda) N_z'(\lambda) d\lambda}$
Measured EDI = 0.9063 x Simulated EML
(Li. et al., 2022)



Method - Simulation

3-channel Radiance simulation



9-channel LARK simulation



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Results - Field Measurement



• White (50) and red (26) are the top and second most used colours for the signboards;

• White has the greatest values of mean luminance, luminance standard deviations, and luminance range;

• Red has the lowest values of mean luminance, luminance standard deviations, and luminance range;

• 42% of the measured data (most white ones and some yellow ones) exceeded the luminance thresholds required by the national code.

Color	Count	Mean lum. (cd/m ²)	Lum. Std. (cd/m²)	Lum. range (cd/m ²)
 Blue	4	196.9	193.7	20.3-391.3
 Green	4	199.6	157.4	44.6-401.1
 Yellow	10	706.0	454.7	139.9-1463.6
Red	26	110.4	86.0	5.4-320.3
White	50	1189.5	796.9	9.4-3188.6



	Photopic lum. MBE _{rel}	Photopic lum. RMSE _{rel}	Circadian lum. MBE _{rel}	Circadian lum. RMSE _{rel}
3-channel	0.66%	3.47%		
9-channel	-0.74%	1.87%	-7.5%	7.8%

- Concerning photopic luminance, both 3-channel and 9-channel methods are able to simulate accurate results;
- Concerning circadian luminance, the Lark 9-channel method is also able to generate reliable results.



• White and blue signboards: circadian luminance values are much greater than photopic values;

• Red and yellow signboards: photopic luminance values are much greater than photopic luminance values;

• Green signboards: circadian luminance values and photopic luminance values are close, while the former is slightly lower than the latter.



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• The white and blue signboards scatter around y=x, and the distances between white signboards and y=x depends on their CCT;

• Both red and yellow signboards are distributed in the upper part of y=x, and the distribution of green signboards is closest to y=x.

Colour	Count	Mean lum. (cd/m ²)	Lum. Std. (cd/m²)	Lum. range (cd/m ²)
Blue	4	196.9	193.7	20.3-391.3
		272.3	218.2	88.4-551.5
Green	4	199.6	157.4	44.6-401.1
		188.5	136.0	55.1-366.7
Yellow	26	110.4	86.0	5.4-320.3
		34.6	54.9	0.5-220.2
Red	10	706.0	454.7	139.9-1463.6
		195.4	111.6	27.0-381.8
White	50	1189.5	796.9	9.4-3188.6
		1231.9	941.0	9.4-3529.4







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Conclusions & Ongoing Work

• Comparing to the measured data, both 3-channel and 9-channel methods are capable of simulating accurate photopic luminance values of colourful signboards;

- The 9-channel method is capable of simulating accurate circadian luminance values of colourful signboards;
- Commonly used colours of self-luminous signboards with the same photopic influence are recommended as below: red > yellow > green > warm white > cool white > blue;

• In the residential areas of Xuanwu District, Nanjing, nearly half (42%) of the measured "internal lightbox" signboards fail to meet the requirements of the "Code for Lighting Design of Urban Nightscape".

- Complete the context validation;
- Propose simplified algorithm of converting photopic luminance/illuminance to circadian luminance/illuminance for commonly used signboard colours;
- Propose design recommendations of commercial lightbox signboards backward, like selections of luminaire (characteristics and count), translucent materials (colours and transmittance), etc;

• Conduct the research in other cities to expand the context/environmental influences.



Thanks for listening.

Any comment or suggestion is appreciated!