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Satisfaction Evaluation on Lightscape of Lantern Festival in China--Based on Fuzzy-IPA Model

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Abstract: Lightscape of the Lantern Festival in China has great significance in recalling historical memory and promoting the development of the tourism economy. The current study aims to optimize the Lantern Festival's lightscape by accessing people's satisfaction. It summarized the history of the Chinese Lantern Festival chronologically and generated lightscape variables from historical documents and field interviews. Considering the ambiguous semantics of satisfaction, the fuzzy comprehensive evaluation was applied to quantify the obscure concept of satisfaction. A total of 391 valid questionnaires collected from three sites (Liwan Lantern Festival in Guangzhou, Splendid China Lantern Festival in Shenzhen, and Qinhuai Confucius Temple Lantern Festival in Nanjing) represented the general situation of the Southern China area. Principal components and weights of lightscape factors extracted by factor analysis pointed main influential aspects of the lightscape. The Fuzzy-IPA model in this study evaluated people's satisfaction with the lightscape of the overall situation and three sites, respectively, and generated improvement strategies for future lightscape design. Subjects' overall satisfaction level for three sites of the Lantern Festival was satisfied (4.072), and their satisfaction levels showed as Nanjing (satisfied, 4.240) > Shenzhen (satisfied, 4.060) > Guangzhou (fair, 3.835). According to the importance and performance of lightscape variables, optimizing suggestions for three sites were proposed from aspects of "cultural expressions", "lamp modeling", "manifestations", and "venue spaces" of lightscape, respectively.

Keywords: Lightscape, Lantern Festival, Satisfaction Evaluation, Fuzzy-IPA Modal

1. Introduction

The Lantern Festival, generally held on the 15th in the first month of the Chinese Lunar New Year, has featured the most prosperous and beautiful lightscape since ancient times. On this festival, people usually take to the streets to appreciate the full moon and various lanterns and lamps, to enjoy performances such as the dragon or lion dances (sometimes combined with lightscape elements), and to guess riddles on lamps. Several versions of the Chinese Lantern Festival's origin have been proposed [1]. One opinion is that the Lantern Festival originated from a lighting practice by Emperor Wu in Han Dynasty (202 B.C.-220 A.D.) in order to pray for blessings. The other one presumes that lighting customs in Lantern Festival were to celebrate the birthday of the Taoist Heavenly Official and pray for his blessing. Additionally, folk tales postulate that lighting on this day could avoid disasters. Those different statements contain the same content--the Lantern Festival symbolizes people's desire to avoid disasters and pray for blessings.

Historically, the Lantern Festival in China was bound up with the background of many past dynasties. It began to take shape in the Sui Dynasty (581A.D.-618A.D.) when fires, lanterns, and fireworks became the main lightscape of the Lantern Festival [2]. During the Tang Dynasty (618A.D.-907A.D.), this festival lasted for three days, and the representative lightscape was the combination of lanterns with trees and buildings [3]. Furthermore, the shapes and colors of lanterns became more diverse. During the Song Dynasty (960A.D.-1279A.D.), when the Lantern Festival was extended to five days, the Aoshan Lantern appeared for the first time, and people were passionate about enjoying the

lantern lightscape [4]. In the Ming Dynasty, the Lantern Festival lasted for ten days. The buildings decorated with colorful lanterns played an essential role in attracting wealthy merchants to invest in Nanjing, the capital city of the early Ming Dynasty [5]. In the period of the Qing Dynasty (1636A.D.-1911A.D.), the palace did not hold the activities of the Lantern Festival. At the same time, folk still celebrated it, and new materials, such as glasses, were used to produce lanterns [6].

Contemporary, high social mobility leaves individuals in a state of spiritual helplessness [7]. The memory of traditional culture contributes to people's spiritual, emotional, and cultural identity [8]. Researchers have long been fascinated by the connection between light and culture [9-13]. Reviewing myriads of historical documents and cases of light culture, Shuoxian Wu- an academician of the Chinese Academy of Science- recognized the great potential of light for presenting regional and traditional culture. Subsequently, he established the discipline of lightscape in China with the aim at exploring light's historical and regional characteristics and its effects on human activities [13]. According to studies on lightscape, light reflecting folk-custom, historical, and regional features is essential to create cultural characteristics and retain people's nostalgia [13, 14]. Previous studies pointed out the extensive presence of light culture associated with human activities in folk-custom festivals [14]. The Lantern Festival is a traditional folk-custom event in China. Its lightscape bearing regional, historical, and cultural connotations contributes to recalling cultural and historical memory and strengthening the urban contexts and features.

Moreover, the Lantern Festival helps bring economic benefits. During the Qinhuai Lantern Festival in 2017, for instance, the total trade revenue of tourism was up to 900 million yuan [15]. Tourists who feel higher satisfaction with the features of travel destinations are more likely to revisit these places [16]. We deduced that higher satisfaction of people with lightscape of the Lantern Festival is beneficial for the revisit behavior, making people more likely to experience the traditional culture and stimulating the festival tourist economy.

The evidence-based lighting design can improve lighting conditions by providing a sound basis for design [17]. In the past, researchers focusing on the evaluation of lightscapes have proposed several optimizing strategies for lightscape design in urban squares [18], historical blocks [19, 20], and classical gardens [21], which have played a crucial role in ameliorating the light condition and preserving its regional characteristics. By investigating people's satisfaction with lightscape of the Lantern Festival, this study aimed at generating proper evidence for its lightscape design in order to preserve historical heritages in urban spaces and promote the economic development of the Lantern Festival.

Generally, people's satisfaction with evaluation objects is an ambiguous concept. While the fuzzy comprehensive evaluation method, based on fuzzy mathematics, allows it to quantify factors with obscure boundaries of people's overall satisfaction with lightscape, which is hard to articulate. In addition, importance-performance analysis (IPA) is a low-cost method to yield important insights into which aspect of the evaluation objects should devote more attention and identify variables consuming too many resources [22]. In previous studies, the Fuzzy-IPA model has evaluated people's satisfaction with urban spaces and tourism and provided several recommendations for improvement [23-25]. Using the Fuzzy-IPA modal, our current research accessed people's degree of satisfaction with lightscape of the Lantern Festival and proposed optimizing strategies for its design.

2. Three Sites

This research conducted field studies on lightscape of Lantern Festivals at three spatial types belonging to the southern China area separately (i.e., Liwan Lantern Festival, as a block park, in Guangzhou; Splendid China Lantern Festival, as a cultural park, in Shenzhen; Qinhuai Confucius Temple Lantern Festival, as a temple architecture, in Nanjing). We analyzed each site's spatial characteristics and collected geographic information about the lightscape and people's satisfaction.

2.1. Liwan Lantern Festival in Guangzhou

The existing historical and cultural blocks and buildings in the Liwan district of Guangzhou are this city's cultural memory and historical heritage. The venue of the Liwan Lantern Festival is mainly located in the Liwan Lake Park and a surrounding river bank of Lychee Bay, where people are permitted to access freely. Most of the lanterns blend in with their surroundings. The content of the lightscape reflected the historical and regional features of the local Xiguan culture. Modern lighting technology reinforced the historical and cultural landscape with lightscape projections on building facades and water curtains (Figure 1).

2.2. Splendid China Lantern Festival in Shenzhen

The Splendid China Lantern Festival site is a cultural park with various ethnic minorities villages that frequently organizes colorful folk-custom festivals and artistic activities. The Lantern Festival is one of the most critical folk-custom festivals in China. During this festival, the park's unique bonfire dancing and other folk performances highlight folkloric characteristics (Figure 2).

2.3. Qinhuai Confucius Temple Lantern Festival in Nanjing

The Qinhuai Lantern Festival in Nanjing, also known as the Jinling Lantern Festival and the Confucius Temple Lantern Festival, originated during the Nan Dynasty (420A.D-589A.D.). It is one of the first national intangible cultural heritages combining lantern exhibitions, lantern fairs, and the Lantern Festival. The Confucius Temple is a building dedicated to Confucius. The Lantern Festival held there is themed on Confucian culture (Figure 3) and has enjoyed an excellent reputation for thousands of years. In recent years, the Confucius Temple, together with the surrounding pedestrian streets and the Qinhuai River, has become a distinctive landscape in Nanjing, attracting many visitors.

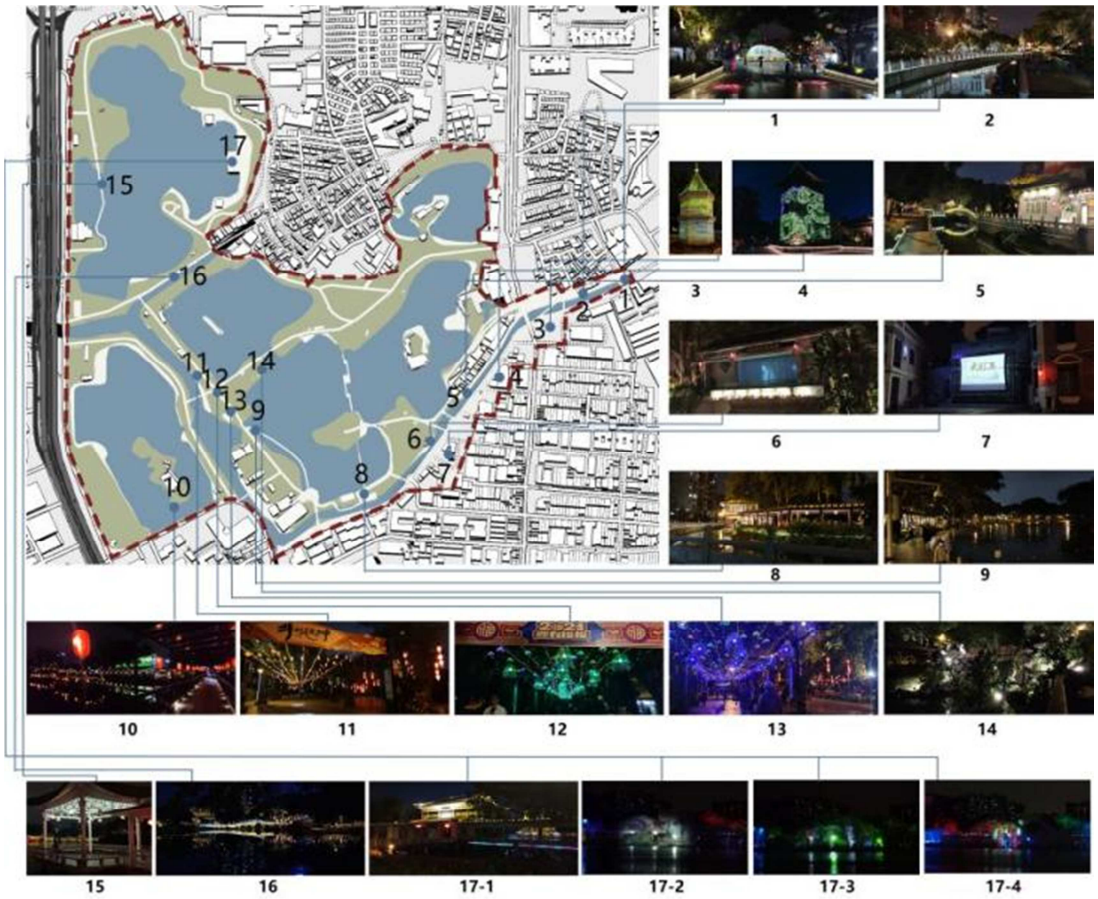

Figure 1. *Lightscape of Liwan Lantern Festival in Guangzhou.*

Figure 2. *Lightscape of Splendid China Lantern Festival in Shenzhen.*

Figure 3. *Lightscape of Qinhuai Confucius Temple Lantern Festival in Nanjing.*

3. Methodology

3.1. Questionnaire

This research used questionnaires to collect people's demographic information and their satisfaction with 24 lightscape variables of the Chinese Lantern Festival generated from ancient books and field interviews before the festival (i.e. cultural expressions of everyday life, cultural expressions of myths and sagas, cultural expressions of historical themes, cultural expressions of regional features, cultural expressions of pop culture, lamp categories, lamp colors, lamp shapes, lamp patterns, lanterns, festival lanterns, lantern riddles, light shows, light art installations, lightscape performance, ground lightscape, near ground lightscape, aerial lightscape, flowing lightscape, lightscape consisting of light and water, lightscape consisting of light and architecture, lightscape combined with smellscape, lightscape combined with soundscape, lightscape combined with human activities). Moreover, a 5-level Likert scale was adopted to evaluate people's satisfaction with these lightscape variables, namely: very unsatisfied (1); unsatisfied (2); fair (3); satisfied (4); very satisfied (5).

3.2. Sampling

Questionnaires were distributed at three sites with different cultural and regional features during the Lantern Festival in Southern China. This study used random sampling to select participants for investigation at different lightscape nodes of each venue, respectively. We calculated the sample size according to the following:

$$N = \frac{z^2 \times \left(P \times (1-P)\right)}{E^2} \quad (1)$$

Where N denotes the sample size, z represents the statistics, E indicates the error, and P refers to the probability value. When the confidence interval is 95%, z equals 1.96, and E equals 5%. If the number of males and females is comparable, P equals 0.5. To achieve a confidence interval above 95%, more than 385 overall questionnaires are required. In addition, factor analysis requires samples with more than five times the factor number. Factor analysis of this study extracted principal factors of three Lantern Festival venues from 24 lightscape variables, which means that the samples should be more than 120. In the field study, we collected 391 valid questionnaires, which imply a confidence interval of more than 95% and meet the requirement of factor analysis.

3.3. Factor Analysis

Factor analysis is a method of reducing a larger number of variables into a smaller number of principal components. This study performed factor analysis to extract the main aspects of the lightscape and calculate the weights of each variable and principal factor, which paved the way for the next step of

fuzzy comprehensive evaluation.

3.4. Fuzzy-IPA Model

3.4.1. Fuzzy Comprehensive Evaluation

Fuzzy comprehensive evaluation has been widely applied in natural and social science. It classified criteria into several levels, with gradually transitioning from lower to higher levels. After comprehensively evaluating factors at the lower level, the results are used to access the higher level. Generally, the evaluation set is expressed by matrices formed from the raw data of the evaluation objects:

$$U = (U_1, U_2 \cdots, U_n) = \begin{bmatrix} (U_{11}, U_{12} \cdots, U_{1j}) \\ \vdots \\ (U_{n1}, U_{n2} \cdots, U_{nk}) \end{bmatrix} = \cdots = \left\{ \begin{bmatrix} \begin{bmatrix} (U_{1\cdots1}, U_{1\cdots2} \cdots, U_{1\cdots p}) \\ \vdots \\ (U_{j\cdots1}, U_{j\cdots2} \cdots, U_{j\cdots q}) \end{bmatrix} \\ \vdots \\ \begin{bmatrix} (U_{n\cdots1}, U_{n\cdots2} \cdots U_{n\cdots s}) \\ \vdots \\ (U_{k\cdots1}, U_{k\cdots2} \cdots, U_{k\cdots t}) \end{bmatrix} \end{bmatrix} \right\} \quad (2)$$

Where U is the factor set, and n is the number of factors of the first level. Each criterion in the first level can divide into second-level sub-criteria, and so are the rest criteria.

It is necessary to calculate the weight distribution of each factor in the evaluation set for the sake of calculating the evaluation of higher-level criteria from the lower-level criteria:

$$W = (W_1, W_2 \cdots, W_n) = \begin{bmatrix} (W_{11}, W_{12} \cdots W_{1j}) \\ \vdots \\ (W_{n1}, W_{n2} \cdots, W_{nk}) \end{bmatrix} = \cdots = \left\{ \begin{bmatrix} \begin{bmatrix} (W_{1\cdots1}, W_{1\cdots2} \cdots, W_{1\cdots p}) \\ \vdots \\ (W_{j\cdots1}, W_{j\cdots2} \cdots, W_{j\cdots q}) \end{bmatrix} \\ \vdots \\ \begin{bmatrix} (W_{n\cdots1}, W_{n\cdots2} \cdots W_{n\cdots s}) \\ \vdots \\ (W_{k\cdots1}, W_{k\cdots2} \cdots, W_{k\cdots t}) \end{bmatrix} \end{bmatrix} \right\} \quad (3)$$

Among them, $W = (W_1, W_2, \cdots, W_n)$ represents the weight of criteria $U = (U_1, U_2 \cdots, U_n)$, $(W_{11}, W_{12} \cdots, W_{1j})$ is the weight of criteria $(U_{11}, U_{12} \cdots U_{1j})$, and so on. In addition, these weights should be normalized.

Then, matrices of higher-level objects will be driven from the raw data of the lower-level objects according to the fuzzy operator $M(\cdot, +)$ and the formula:

$$B_i = W_i \times R_i \quad (4)$$

Where R_i indicates matrices of the evaluation set, Wi donates the weight of the corresponding set, Bi represents matrices of a higher level. Ultimately, it is possible to solve the comprehensive evaluation set by the formula:

$$\text{Set } A = W \times B \quad (5)$$

To evaluate the value of the comprehensive criteria, formula (6) is applied for defuzzification to calculate the evaluation value of each criteria level with formula (7), where H denotes the satisfaction degree: 1, 2, 3, 4, 5.

$$\text{set } V = (V_1, V_2, V_3, V_4, V_5) = (1, 2, 3, 4, 5) \quad (6)$$

$$E = B \times H \quad (7)$$

3.4.2. Importance-Performance Analysis (IPA)

IPA is a low-cost method to provide strategies for optimizing evaluation objects. IPA combined with the fuzzy comprehensive evaluation can build a Fuzzy-IPA model. There are four quadrants in the IPA chart, corresponding to four ameliorating strategies accordingly (Figure 4). These four quadrants can be divided using the average importance value as the horizontal coordinate and the average performance value as the vertical coordinate. Factors in the first quadrant are high importance and performance, and we must keep up with the current work. Factors in the second quadrant are low importance and high performance. They are possibly over-killed and require less investment. Factors in the third quadrant are low importance and performance, with a low priority on optimization. In the fourth quadrant, factors are high importance and low performance, which should concentrate on optimization.

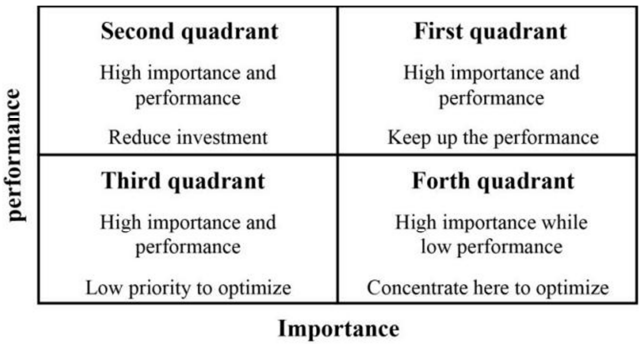

Figure 4. *IPA quadrants.*

4. Results

4.1. Participant Demographics

A total of 391 valid questionnaires were collected through field studies on three sites of the Lantern Festivals. Table 1 shows the contents and categories of participant demographics of these places:

Table 1. *Participant demographics.*

Statistical contents	Categories	Quantities and Ratios			
		The Liwan Lantern Festival	The Splendid China Lantern Festival	The Qinhuai Confucius Temple Lantern Festival	Total
Gender	Man	57	77	95	229 (58.57%)
	Female	48	62	52	162 (41.43%)
Age	≤12	5	6	0	11 (2.81%)
	13-17	4	3	6	13 (3.32%)
	18-28	64	68	98	230 (58.82%)
	29-49	26	53	36	115 (29.41%)
	50-65	5	8	5	18 (4.60%)
	>65	1	1	2	4 (1.02%)
Education	No more than high school	22	24	17	65 (16.62%)
	Technical college	18	23	26	67 (17.14%)
	Undergraduate	44	61	82	187 (47.83%)
	Graduate	21	31	22	74 (18.93%)
Occupation	Enterprise and Public Institution	46	78	43	167 (42.71%)
	Self-employed	6	7	10	23 (5.88%)
	Freelance	8	17	19	44 (11.25%)
	Students	31	20	46	97 (24.81%)
	Retired	2	1	5	8 (2.05%)
	Other	12	16	22	50 (12.79%)
Local living time	<1 year	18	28	97	143 (36.57%)
	1-3 year	22	27	17	66 (16.88%)
	3-5 year	11	11	11	33 (8.44%)
	5-10 year	12	26	5	43 (11.00%)
	>10 year	42	46	17	105 (26.85%)

4.2. Results of Factor Analysis

Based on the overall data from three sites of the Lantern Festival, the reliability of Cronbach α in this research was 0.937, demonstrating that the questionnaire design was reliable. The values of the KMO and Bartlett tests were 0.919 and 0, respectively, suggesting that these variables were valid and suitable for factor analysis.

In this study, 24 lightscape variables were summarized and subjected to principal component analysis to extract principal components from the overall data. Varimax orthogonal rotation extracted factors with loading values greater than 0.5 and classified these factors into different principal components. The variable "lightscape performance" did not belong to any other principal components and was removed. According to factor loading, the remaining 23 variables were categorized into four principal components with a total variance devoting rate of 78.313% (Table 2). Meanwhile, factor weights and their mean value (0.043) will be applied for the following fuzzy comprehensive evaluation.

Table 2. *Factor analysis of variables of the lightscape.*

	F1: Cultural expressions of lightscape	F2: Lamp modeling of lightscape	F3: Manifestations of lightscape	F4: Venue spaces of lightscape
Eigen value	4.467	4.019	4.147	5.377
Weight	22.16%	17.60%	22.19%	38.05%
Variance	19.421%	17.473%	18.032%	23.386%
Factor, Loading, Weight	F11: cultural expressions of everyday life 0.735, 4.37% F12: cultural expressions of myths and sagas 0.742, 4.42% F13: cultural expressions of historical themes 0.763, 4.47% F14: cultural expressions of regional features 0.720, 4.46% F15: cultural expressions of pop culture 0.728, 4.44%	F21: lamp categories 0.638, 4.40% F22: lamp colors 0.745, 4.27% F23: lamp shapes 0.749, 4.47% F24: lamp patterns 0.712, 4.46%	F31: lanterns 0.604, 4.57% F32: festival lanterns 0.604, 4.46% F33: lantern riddles 0.725, 4.12% F34: light shows 0.723, 4.34% F35: light art installations 0.658, 4.70%	F41: ground lightscape 0.628, 4.39% F42: near ground lightscape 0.623, 4.13% F43: aerial lightscape 0.589, 4.43% F44: flowing lightscape 0.645, 4.28% F45: lightscape consisting of light and water 0.625, 4.21% F46: lightscape consisting of light and architecture 0.635, 4.58% F47: lightscape combined with smellscape 0.609, 4.26% F48: lightscape combined with soundscape 0688, 3.99% F49: lightscape combined with human activities 0.749, 3.78%

4.3. Results of the Fuzzy Comprehensive Evaluation

The fuzzy comprehensive evaluation matrices were constructed using the results derived from factor analysis. Lightscape evaluation sets and subsets were established according to lightscape factors and principal components, as shown in table 3:

Table 3. *Evaluation criteria system.*

Evaluation set	Evaluation subset
U1 Cultural expressions of lightscape	U11 cultural expressions of everyday life, U12 cultural expressions of myths and sagas, U13 cultural expressions of historical themes, U14 cultural expressions of regional features, U15 cultural expressions of pop culture
U2 Lamp modeling of lightscape	U21 lamp categories, U22 lamp colors, U23 lamp shapes, U24 lamp patterns
U3 Manifestations of lightscape	U31 lanterns, U32 festival lanterns, U33 lantern riddles, U34 light shows, U35 light art installations
U4 Venue spaces of lightscape	U41 ground lightscape, U42 near ground lightscape, U43 aerial lightscape, U44 flowing lightscape, U45 lightscape consisting of light and water, U46 lightscape consisting of light and architecture, U47 lightscape combined with smellscape, U48 lightscape combined with soundscape, U49 lightscape combined with human activities

$$U = (U_1, U_2, U_3, U_4) = \begin{bmatrix} (U_{11},\ U_{12},\ U_{13},\ U_{14},\ U_{15}) \\ (U_{21},\ U_{22},\ U_{23},\ U_{24}) \\ (U_{31},\ U_{32},\ U_{33},\ U_{34},\ U_{35}) \\ (U_{41},\ U_{42},\ U_{43},\ U_{44},\ U_{45},\ U_{46},\ U_{47},\ U_{48},\ U_{49}) \end{bmatrix} \tag{8}$$

$$W = (W_1,\ W_2,\ W_3,\ W_4) = (0.222, 0.176, 0.222, 0.381) =$$

$$\begin{bmatrix} (W_{11},\ W_{12},\ W_{13},\ W_{14},\ W_{15}) \\ (W_{21},\ W_{22},\ W_{23},\ W_{24}) \\ (W_{31},\ W_{32},\ W_{33},\ W_{34},\ W_{35}) \\ (W_{41},\ W_{42},\ W_{43},\ W_{44},\ W_{45},\ W_{46},\ W_{47},\ W_{48},\ W_{49}) \end{bmatrix} = \begin{bmatrix} (0.197, 0.199, 0.202, 0.201, 0.200) \\ (0.250, 0.243, 0.254, 0.253) \\ (0.206, 0.201, 0.186, 0.196, 0.212) \\ (0.115, 0.109, 0.116, 0.112, 0.111, 0.120, 0.112, 0.105, 0.099) \end{bmatrix} \tag{9}$$

4.3.1. Fuzzy Comprehensive Evaluation on Lightscape of the Overall Situation

Evaluation matrices R1, R2, R3, and R4 represented the proportions of participants who evaluated a certain satisfaction degree in the overall data from three sites.

$$R_1 = \begin{bmatrix} 0.005 & 0.005 & 0.256 & 0.414 & 0.320 \\ 0.005 & 0.020 & 0.271 & 0.379 & 0.325 \\ 0.010 & 0.013 & 0.215 & 0.422 & 0.340 \\ 0.008 & 0.018 & 0.210 & 0.412 & 0.353 \\ 0.005 & 0.026 & 0.246 & 0.412 & 0.312 \end{bmatrix} \tag{10}$$

$$R_2 = \begin{bmatrix} 0.003 & 0.005 & 0.212 & 0.437 & 0.343 \\ 0.003 & 0.005 & 0.166 & 0.463 & 0.363 \\ 0.003 & 0.018 & 0.176 & 0.442 & 0.361 \\ 0.005 & 0.018 & 0.176 & 0.419 & 0.381 \end{bmatrix} \tag{11}$$

$$R_3 = \begin{bmatrix} 0.008 & 0.010 & 0.171 & 0.450 & 0.361 \\ 0.008 & 0.010 & 0.169 & 0.448 & 0.363 \\ 0.010 & 0.028 & 0.235 & 0.404 & 0.320 \\ 0.005 & 0.015 & 0.171 & 0.458 & 0.348 \\ 0.008 & 0.013 & 0.210 & 0.425 & 0.345 \end{bmatrix} \tag{12}$$

$$R_4 = \begin{bmatrix} 0.010 & 0.013 & 0.215 & 0.435 & 0.325 \\ 0.008 & 0.018 & 0.197 & 0.430 & 0.345 \\ 0.008 & 0.023 & 0.194 & 0.440 & 0.332 \\ 0.010 & 0.036 & 0.194 & 0.430 & 0.327 \\ 0.008 & 0.018 & 0.146 & 0.460 & 0.366 \\ 0.008 & 0.023 & 0.141 & 0.478 & 0.350 \\ 0.013 & 0.059 & 0.233 & 0.384 & 0.312 \\ 0.010 & 0.046 & 0.215 & 0.389 & 0.335 \\ 0.010 & 0.038 & 0.192 & 0.425 & 0.322 \end{bmatrix} \tag{13}$$

Comprehensive evaluation sets of criteria in overall data were calculated according to the blurring operator M(·, +) and formula (4).

$$B_1 = W_1 \times R_1 = (0.007\ 0.016\ 0.239\ 0.408\ 0.330)$$

$$B_2 = W_2 \times R_2 = (0.004\ 0.012\ 0.183\ 0.440\ 0.362)$$

$$B_3 = W_3 \times R_3 = (0.008\ 0.015\ 0.191\ 0.437\ 0.348)$$

$$B_4 = W_4 \times R_4 = (0.009\ 0.030\ 0.191\ 0.431\ 0.335)$$

Then, the defuzzification process was performed to calculate the evaluation value of the criteria. According to formula (6), $E_1 = 4.038$, $E_2 = 4.147$, $E_3 = 4.099$, $E_4 = 4.041$. The value of Ei suggested that people's overall satisfaction with principal factors of lightscape (i.e., "Cultural expressions" "Lamp modeling" "Manifestations", and "Venue spaces" of lightscape).

Based on the weights of the principal factors, the fuzzy comprehensive evaluation value $E = 4.073$ was calculated by $A = (0.007\ 0.020\ 0.200\ 0.429\ 0.342)$ following the formula (5).

Moreover, the mean value of the lightscape sub-criteria was calculated as 3.967, which indicated the average performance of lightscape variables in three sites and was applied to the following IPA process.

4.3.2. Fuzzy Comprehensive Evaluation on Lightscape of Three Sites

Similarly, evaluation matrices were established for three sites of the Lantern Festival. Then, the satisfaction degrees of these factors were calculated and applied as performance values of lightscape factors in the following IPA process (Figures 5-8).

Lightscape factor matrics for the Liwan Lantern Festival

were R11, R12, R13, and R14, indicating the principal components "cultural expressions" "lamp modeling" "manifestations", and "venue spaces" of lightscape, respectively.

$$R_{11}=\begin{bmatrix}0.010 & 0 & 0.343 & 0.420 & 0.229\\ 0.010 & 0.029 & 0.343 & 0.410 & 0.210\\ 0.010 & 0.010 & 0.257 & 0.486 & 0.238\\ 0.010 & 0 & 0.267 & 0.467 & 0.257\\ 0.010 & 0.019 & 0.314 & 0.448 & 0.210\end{bmatrix} \quad (14)$$

$$R_{12}=\begin{bmatrix}0.010 & 0 & 0.289 & 0.467 & 0.238\\ 0.009 & 0 & 0.220 & 0.514 & 0.257\\ 0.010 & 0.029 & 0.248 & 0.457 & 0.257\\ 0.019 & 0.019 & 0.267 & 0.420 & 0.267\end{bmatrix} \quad (15)$$

$$R_{13}=\begin{bmatrix}0.019 & 0.010 & 0.257 & 0.505 & 0.210\\ 0.019 & 0.010 & 0.248 & 0.486 & 0.238\\ 0.019 & 0.029 & 0.324 & 0.400 & 0.229\\ 0.019 & 0.029 & 0.219 & 0.523 & 0.191\\ 0.019 & 0.019 & 0.267 & 0.495 & 0.200\end{bmatrix} \quad (16)$$

$$R_{14}=\begin{bmatrix}0.019 & 0.029 & 0.305 & 0.476 & 0.171\\ 0.029 & 0.019 & 0.276 & 0.448 & 0.219\\ 0.019 & 0.048 & 0.257 & 0.457 & 0.210\\ 0.029 & 0.041 & 0.305 & 0.391 & 0.210\\ 0.019 & 0.029 & 0.191 & 0.524 & 0.238\\ 0.019 & 0.019 & 0.152 & 0.562 & 0.248\\ 0.029 & 0.067 & 0.371 & 0.343 & 0.191\\ 0.019 & 0.076 & 0.343 & 0.343 & 0.210\\ 0.029 & 0.076 & 0.248 & 0.476 & 0.181\end{bmatrix} \quad (17)$$

Lightscape factor matrics of the Splendid China Lantern Festival were R21, R22, R23, and R24.

$$R_{21}=\begin{bmatrix}0 & 0.014 & 0.245 & 0.460 & 0.281\\ 0 & 0.022 & 0.295 & 0.374 & 0.309\\ 0.007 & 0.014 & 0.245 & 0.432 & 0.302\\ 0.007 & 0.014 & 0.223 & 0.432 & 0.324\\ 0 & 0.029 & 0.288 & 0.403 & 0.281\end{bmatrix} \quad (18)$$

$$R_{22}=\begin{bmatrix}0 & 0.017 & 0.209 & 0.460 & 0.324\\ 0 & 0.014 & 0.130 & 0.482 & 0.374\\ 0 & 0.014 & 0.151 & 0.489 & 0.345\\ 0 & 0.014 & 0.158 & 0.471 & 0.356\end{bmatrix} \quad (19)$$

$$R_{23}=\begin{bmatrix}0.007 & 0.014 & 0.166 & 0.468 & 0.345\\ 0.007 & 0.007 & 0.151 & 0.475 & 0.360\\ 0.014 & 0.036 & 0.237 & 0.446 & 0.259\\ 0.007 & 0.022 & 0.166 & 0.489 & 0.317\\ 0.007 & 0.007 & 0.187 & 0.460 & 0.338\end{bmatrix} \quad (20)$$

$$R_{24}=\begin{bmatrix}0.014 & 0.014 & 0.201 & 0.439 & 0.331\\ 0 & 0.029 & 0.166 & 0.475 & 0.331\\ 0.007 & 0.022 & 0.166 & 0.504 & 0.302\\ 0.007 & 0.029 & 0.187 & 0.460 & 0.309\\ 0.007 & 0.022 & 0.144 & 0.475 & 0.353\\ 0.007 & 0.022 & 0.122 & 0.504 & 0.345\\ 0.007 & 0.072 & 0.216 & 0.432 & 0.273\\ 0.014 & 0.029 & 0.194 & 0.417 & 0.338\\ 0.007 & 0.022 & 0.201 & 0.446 & 0.317\end{bmatrix} \quad (21)$$

Lightscape factor matrics of the Qinhuai Confucius Temple Lantern Festival were R31, R32, R33, and R34.

$$R_{31}=\begin{bmatrix}0.007 & 0 & 0.204 & 0.367 & 0.422\\ 0.007 & 0.014 & 0.193 & 0.361 & 0.422\\ 0.014 & 0.014 & 0.157 & 0.367 & 0.449\\ 0.007 & 0.034 & 0.157 & 0.354 & 0.449\\ 0.007 & 0.027 & 0.157 & 0.395 & 0.415\end{bmatrix} \quad (22)$$

$$R_{32}=\begin{bmatrix}0 & 0.007 & 0.163 & 0.395 & 0.435\\ 0 & 0 & 0.163 & 0.408 & 0.429\\ 0 & 0.014 & 0.150 & 0.388 & 0.449\\ 0 & 0.009 & 0.143 & 0.388 & 0.456\end{bmatrix} \quad (23)$$

$$R_{33}=\begin{bmatrix}0 & 0.007 & 0.166 & 0.395 & 0.483\\ 0 & 0.014 & 0.129 & 0.395 & 0.456\\ 0 & 0.020 & 0.170 & 0.367 & 0.442\\ 0 & 0 & 0.143 & 0.367 & 0.490\\ 0 & 0.014 & 0.190 & 0.340 & 0.456\end{bmatrix} \quad (24)$$

$$R_{34}=\begin{bmatrix}0 & 0 & 0.163 & 0.401 & 0.429\\ 0 & 0.007 & 0.170 & 0.374 & 0.449\\ 0 & 0.007 & 0.177 & 0.367 & 0.449\\ 0 & 0.020 & 0.122 & 0.429 & 0.429\\ 0 & 0.007 & 0.116 & 0.401 & 0.470\\ 0 & 0.027 & 0.150 & 0.395 & 0.429\\ 0.007 & 0.041 & 0.150 & 0.367 & 0.435\\ 0 & 0.041 & 0.143 & 0.395 & 0.422\\ 0 & 0.027 & 0.243 & 0.374 & 0.429\end{bmatrix} \quad (25)$$

Fuzzy comprehensive evaluation values of lightscapes in three sites of the Lantern Festival were calculated according to similar processes. The value of 3.972 for the Liwan Lantern Festival (Guangzhou) had a fair satisfaction degree. The evaluation values of the Splendid China Lantern Festival (Shenzhen) and the Qinhuai Confucius Temple Lantern Festival (Nanjing) were 4.060 and 4.240, respectively, whose satisfaction degrees were satisfied.

4.4. The Result of IPA

The mean value of the importance of lightscape factors was calculated as 0.043 by averaging the weights of all factors, which functioned as the horizontal axis of the IPA coordinate system. While the mean value of performance (i.e., degree of satisfaction) was 4.055, acting as the vertical axis of the IPA coordinate system.

4.4.1. Factors in Cultural Expressions of Lightscape

Figure 5 illustrates the distribution of factors of cultural expressions of lightscape in IPA quadrants. Factors of the Liwan Lantern Festival and the Splendid China Lantern Festival were located in the fourth quadrant, reflecting an urgent necessity for improvements. Factors of the Qinhuai Confucius Temple Lantern Festival were in the first quadrant and just required to maintain the performance in the future.

4.4.2. Factors in Lamp Modeling of Lightscape

As presented in Figure 6, in the Liwan Lantern Festival, F21 (lamp categories), F23 (lamp shapes), and F24 (lamp patterns) lay in the fourth quadrant and require to optimize; while F22 (lamp colors) was in the third quadrant, with low priority for improvements. In the Splendid China Lantern Festival and the

Qinhaui Confucius Temple Lantern Festival, F21 (lamp categories), F23 (lamp shapes), and F24 (lamp patterns) were in the first quadrant, which just needed to keep up the current performance. On the other hand, F22 (lamp colors) of the latter two Lantern Festivals were in the second quadrant, with excessive investments and requiring reduced inputs.

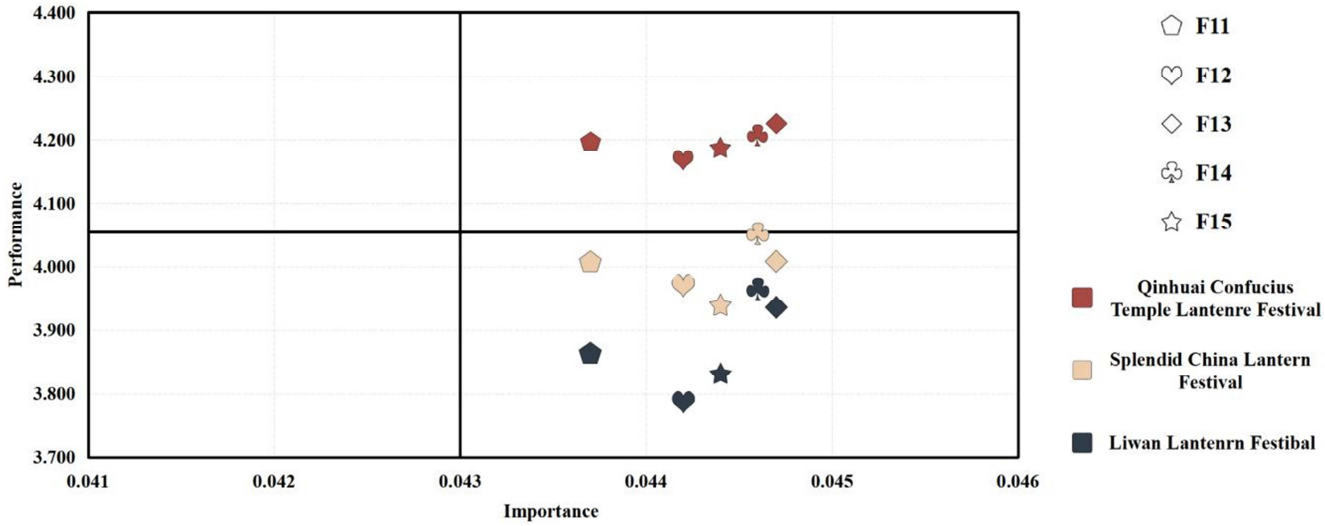

Figure 5. *Factors of cultural expressions of lightscape.*

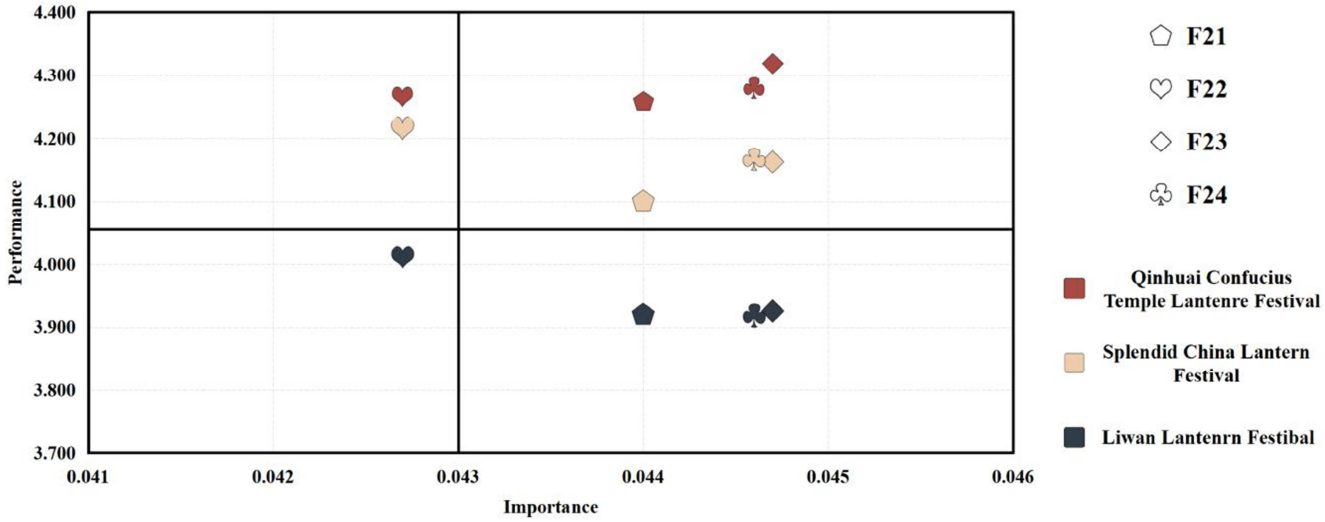

Figure 6. *Factors of lamp modeling of lightscape.*

4.4.3. Factors of Manifestations of Lightscape

Figure 7 exhibits the factors distribution of manifestations of lightscape in IPA quadrants. F33 (lantern riddles) of the Liwan Lantern Festival was in the third quadrant and thus had low priority to optimize. In contrast, its F31 (lanterns), F32 (festival lanterns), F34 (light shows), and F35 (light art installations) belong to the fourth quadrant, indicating the high priority for optimization. In the Splendid China Lantern Festival and the Qinhuai Confucius Lantern Festival, F31 (lanterns), F32 (festival lanterns), F34 (light shows), and F35 (light art installations) were in the first quadrant, which need to maintain the current performance. However, F33 (light shows) of the Splendid China Lantern Festival was in the third quadrant with a low priority of optimization, and F33 (light shows) of the Qinhuai Confucius Temple Lantern Festival was in the second quadrant, which may be over-invested, and can be reduced in the future.

4.4.4. Factors of Venue Spaces of Lightscape

Figure 8 displays the distribution of factors of venue spaces of lightscape in IPA quadrants. In the Liwan Lantern Festival, F41 (ground lightscape), F43 (aerial lightscape), and F46 (lightscape consisting of light and water) were distributed in the fourth quadrant and should be concentrated on the optimization. While F42 (near ground lightscape), F44 (flowing lightscape), F45 (lightscape consisting of light and water), F47 (lightscape combined with smellscape), F48 (lightscape combined with soundscape), and F49 (lightscape combined with human activities) were located in the third quadrant and hence had low priority to improve the performance.

In the Splendid China Lantern Festival, F41 (ground lightscape), F43 (aerial lightscape), and F46 (lightscape consisting of light and water) were situated in the first

quadrant and therefore just required to maintain excellent performance. F42 (near ground lightscape) and F45 (lightscape consisting of light and water) lay in the second quadrant and maybe need to reduce the investment appropriately. In contrast, F44 (flowing lightscape), F47 (lightscape combined with smellscape), F48 (lightscape combined with soundscape), and F49 (lightscape combined with human activities) were within the third quadrant, with low priority for improvement.

In the Qinhuai Confucius Temple Lantern Festival, F41 (ground lightscape), F43 (aerial lightscape), and F46 (lightscape consisting of light and water) were in the first quadrant and needed to sustain the performance. F42 (near ground lightscape), F44 (flowing lightscape), F45 (lightscape consisting of light and water), F47 (lightscape combined with smellscape), F48 (lightscape combined with soundscape), and F49 (lightscape combined with human activities) belong to the second quadrant and required to reduce the investment in the future.

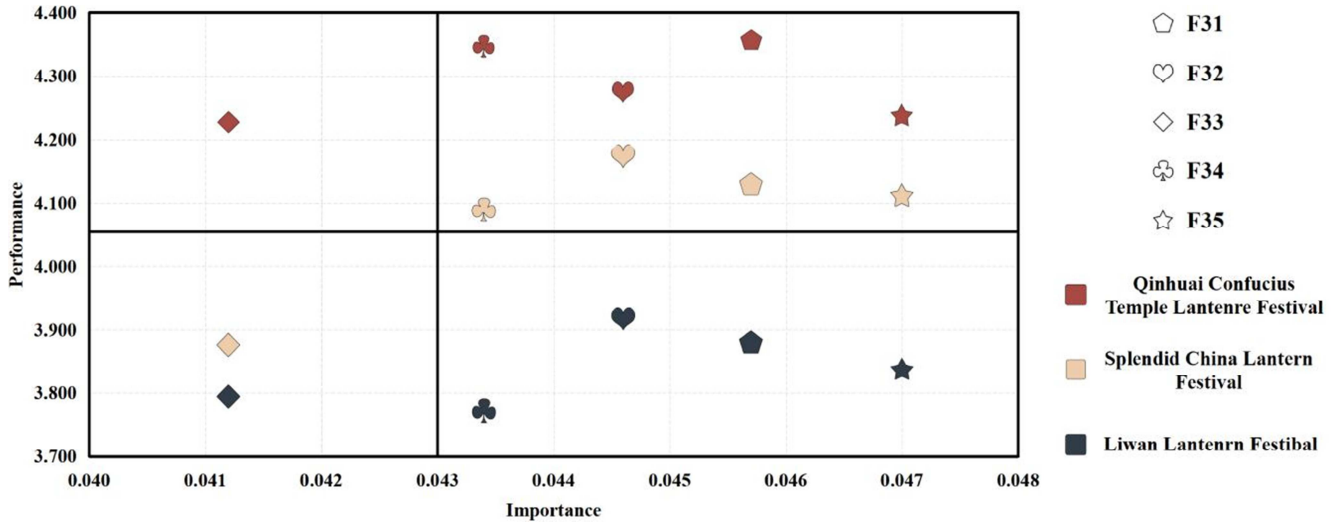

Figure 7. *Factors of manifestations of lightscape.*

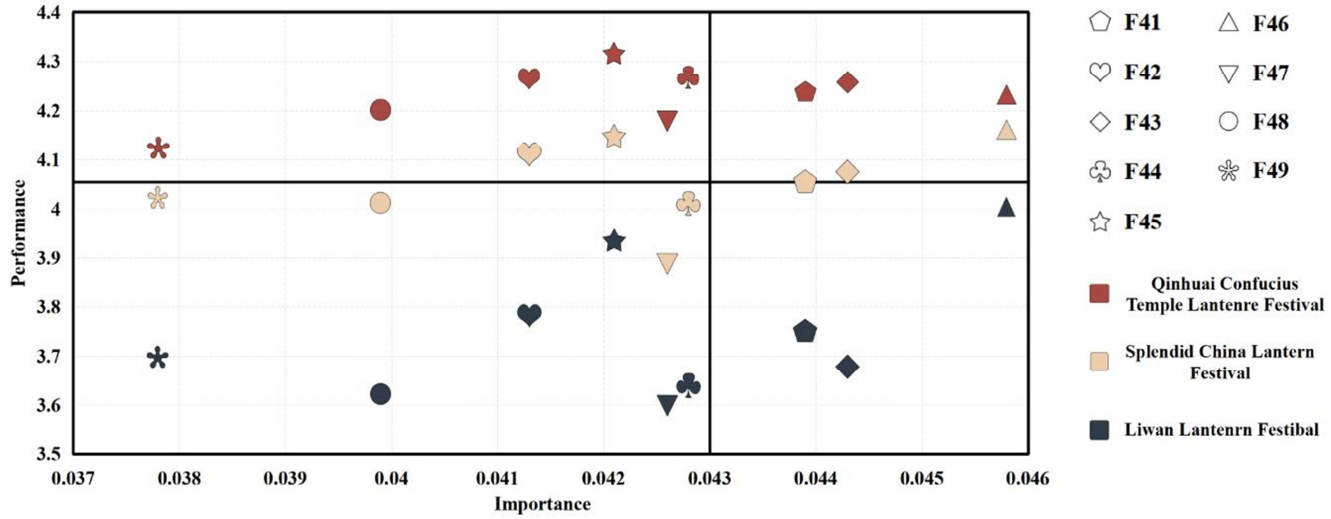

Figure 8. *Factors of venue spaces of lightscape.*

5. Conclusions

The Lantern Festival is one of the most important traditional festivals in China, in which lightscape helps evoke people's historical memories, settle their souls, and stimulate the development of the tourism economy. This study attempts to provide appropriate evidence for optimizing lightscape design of the Lantern Festival by investigating people's satisfaction. This paper concluded lightscape variables from historical documents and a field study, and extracted the principal components of lightscape variables by factor analysis. Based on the fuzzy-IPA modal, it calculated subjects' satisfaction with lightscape of the Lantern Festival and generated optimizing strategies for lightscape design.

According to the fuzzy comprehensive evaluation, people's satisfaction with lightscape of the overall data of the Lantern Festival was 4.073 (satisfied). The satisfaction with lightscape of the Liwan Lantern Festival (Guangzhou) was 3.972 (fair)<4.060 (satisfied) for the satisfaction with the Splendid China Lantern Festival (Shenzhen)<4.240 (satisfied) for the Qinhuai Confucius Lantern Festival (Nanjing). IPA provided

different optimizing strategies for lightscape of three sites of the Lantern Festival.

6. Discussions

The fuzzy decision support system contributes to providing valid evidence for decision-making. In previous studies, researchers have developed the fuzzy decision support system and provided policymakers with urban development policies [23-26]. Based on fuzzy mathematics, the Fuzzy-IPA model in this study helps evaluate obscure semantics satisfaction with lightscape and generate optimizing suggestions for future lightscape design.

In the Liwan Lantern Festival, F11 (cultural expressions of everyday life), F12 (cultural expressions of myths and sagas), F13 (cultural expressions of historical themes), F14 (cultural expressions of regional features), F15 (cultural expressions of pop culture), F21 (lamp categories), F23 (lamp shapes), F24 (lamp patterns), F31 (lanterns), F32 (festival lanterns), F34 (lantern riddles), F35 (light art installations), F41 (ground lightscape), F43 (aerial lightscape), and F46 (lightscape consisting of light and architecture) were located in the fourth quadrant. These factors with high importance and low performance urgently needed optimization. Other lightscape factors were in the third quadrant, with low priority for improving the performance.

In the Splendid China Lantern Festival, F11 (cultural expressions of everyday life), F12 (cultural expressions of myths and sagas), F13 (cultural expressions of historical themes), F14 (cultural expressions of regional features), and F15 (cultural expressions of pop culture) were distributed in the fourth quadrant and should be prioritized for optimization. F22 (lamp colors), F42 (flowing lightscape), and F45 (lightscape consisting of light and water) were in the second quadrant, requiring a reduction of the inputs. Other lightscape factors were in the third quadrant of IPA, with low priority for ameliorating.

In the Qinhuai Confucius Temple Lantern Festival, F22 (lamp colors), F33 (lantern riddles), F42 (near ground lightscape), F44 (flowing lightscape), F45 (lightscape consisting of light and water), F47 (lightscape combined with smellscape), F48 (lightscape combined with soundscape), and F49 (lightscape combined with human activities) were in the second quadrant. These lightscape factors were over-invested and should decrease the investment in the future. Other factors lay in the first quadrant, which need to continue the excellent performance.

In this paper, lightscape information and people's subjective evaluations were collected in the fields. Future studies can access people's responses to lightscape both in the field and laboratory simulations to evaluate the accuracy of laboratory lightscape simulations. In addition, objective methods are also promising in assessing subjects' responses to lightscape (e.g., eye tracking, electrocorticography, electroencephalography, and electrocardiography).

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