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Civil architectural lighting problems relative energy saving design analysis

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ABSTRACT

By considering civil architecture region climatic differences, adopt fuzzy analytic hierarchy process mathematical method to make researches on architectural lighting relative energy saving problems. On the basis of lighting, take comprehensive consideration together with architectural energy saving factors, look for the balance point between the two. Utilize fuzzy mathematics comprehensive evaluation method, according to indicators factors, it defines evaluation system, and makes evaluation research on lighting energy saving design's relative strategy. Conclusion thought that optimize overall architecture layout and optimize architecture form design are more important than daylight opening design. Architectural overall layout is an important method of architectural lighting and energy saving.

KEYWORDS

Civil architecture; Lighting and energy saving; Region and climate; Fuzzy mathematics.

INTRODUCTION

Science and technology have been rapidly developed in 21st century; people's living standards and qualities are constantly improving. Urban architecture adopts more advanced technology to promote people lodging experience quality. Urban civil architecture artistic, energy saving, lighting optimization and others let urban architecture overall levels to far surpass that of 20th century.

For China, national land areas are wide, different regions climates and environments differences are great, so that causes each place civil architecture design ways being different. Combine with regional climates; fully consider energy saving factors involved civil architecture lighting is very necessary. Researches on the aspect are quite a lot, from which Wang Hong-Zhen during researching architecture lighting, she applied software to do simulation research on lighting on region climatic conditions[1]. Li Yong analyzed regional climates and environments, and regarded them as premise to do research on architecture lighting and energy saving[2]. Xie Hao researched on dwelling adopted natural light, conclusion thought that natural light could become fashion, promote indoors environment and reduce architectural energy consumption[3]. Fan Xiao-Dong started from overall architectural lighting and energy saving design, considered design comprehensive factors to research on architectural design thought[4].

By different region climatic conditions, the paper defines lighting and energy saving design notes. And research on civil architectural lighting and energy saving relative problems. According to fuzzy hierarchical mathematical methods, establish mathematical model to make quantization research on civil architectural lighting and energy saving, find out reasonable design schemes.

CIVIL ARCHITECTURAL LIGHTING AND ENERGY SAVING

Civil architectural lighting standard has evaluation indicators, even lighting standards under different regional climates environments that can also amend and use, common used lighting standards are six.

Illumination, different standards require different illumination values, illumination is one of important evaluation indicators in lighting. Daylight factors, it refers to indoors one place illumination value and outdoors same conditions illumination values ratio in case of cloudy days. Besides, there are useful daylight illuminance, daylight autonomy, continuous daylight autonomy, and annual Light Exposure.

In some extent, lighting and energy saving are mutual contradicted, lighting effects is good as light opening area increases that let energy facilities to increase. Lighting and thermal environment energy saving are mutual conflicted. Therefore architectural lighting and energy saving should be mutual considered, take their optimal values, let lighting and energy saving to compromise and arrive at optimization that gets close to ideal. In different region climatic environments, lighting design on civil architecture should start from overall design. Plan architectural overall layout; optimize architectural form; reasonable daylight opening shape and material selection. Lighting and energy saving can consider from architecture overall layout and architectural form, good architectural design can utilize its acquired sufficient lighting, ensure lighting and energy saving's balance. Architectural materials selection and daylight opening design can ensure architectural internal consumption to be reduced, such as insulating layer's application in architectural walls. Relative model is as Figure 1.

FUZZY HIERARCHICAL MULTIPLE DECISION MATHEMATICAL MODEL

Fuzzy refers to objective things critical state or transient state that cannot distinguish in classification process, it has no clearly distinction. Fuzzy comprehensive evaluation is a kind of method that integrating multiple factors or indicators to make fuzzy evaluation on evaluated system, applying

fuzzy relationships synthetic principles to calculate system membership grades, and defining evaluation result.

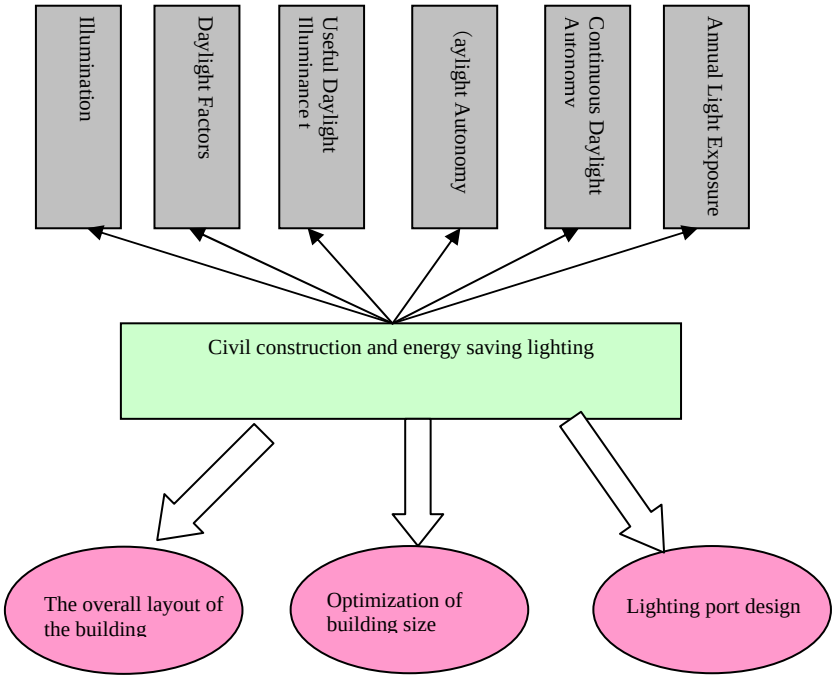

Figure 1 : Civil architectural lighting and energy saving factors figure

Fuzzy evaluation steps

(1) Establish evaluation objects factor domain of discourse U, $U=(u_1,u_2\cdots,u_n)$, in the paper.

(2) Define domain of discourse factors' qualitative remarks grade V, $V(v_1,v_2,\cdots,v_n)$, remarks are set as (very effective, relative effective, effective, relative effectless, very effectless), is expressed by $v_n(n=1,2,3,4,5,)$.

(3) Define scheme domain of discourse F, in the paper, schemes are $F=(f_1,f_2,f_3)$, 1, plan architectural overall layout, 2 optimize architecture form, 3, reasonable daylight opening shape and materials selection. By factor corresponding remarks domain of discourse membership, establish fuzzy relation matrix, by experts checking and scoring, it provides scheme one corresponds to membership TABLE 1 according to following table.

TABLE 1 : Membership value table

	Very effective v_1	**Relative effective** v_2	**Effective** v_3	**Relative effectless** v_4	**Very effectless** v_5
u_1	0.16	0.42	0.23	0.12	0.07
u_2	0.54	0.21	0.16	0.09	0
u_3	0.53	0.23	0.14	0.10	0
u_4	0.13	0.19	0.44	0.18	0.06
u_5	0.35	0.30	0.15	0.19	0.01
u_6	0.30	0.21	0.30	0.1	0.08

Therefore, it defines scheme to factors membership function relationship, use matrix to express:

$$R_1=\begin{pmatrix}0.16 & 0.42 & 0.23 & 0.12 & 0.07\\ 0.54 & 0.21 & 0.16 & 0.09 & 0\\ 0.53 & 0.23 & 0.14 & 0.10 & 0\\ 0.13 & 0.19 & 0.44 & 0.18 & 0.06\\ 0.35 & 0.30 & 0.15 & 0.19 & 0.01\\ 0.30 & 0.12 & 0.30 & 0.1 & 0.08\end{pmatrix}$$

Among them, r_{ij} represents factor domain of discourse factors memberships to remarks grade domain of discourse. Sub matrix is fuzzy matrix. Similarly it can get six schemes' fuzzy relations matrixes are respectively as following.

$$R_2=\begin{pmatrix}0.25 & 0.46 & 0.18 & 0.11 & 0\\ 0.28 & 0.14 & 0.39 & 0.19 & 0\\ 0.48 & 0.15 & 0.15 & 0.12 & 0\\ 0.13 & 0.23 & 0.28 & 0.19 & 0.17\\ 0.39 & 0.23 & 0.18 & 0.12 & 0.08\\ 0.21 & 0.28 & 0.26 & 0.15 & 0.08\end{pmatrix}$$

$$R_3=\begin{pmatrix}0.21 & 0.46 & 0.33 & 0 & 0\\ 0.28 & 0.39 & 0.33 & 0 & 0\\ 0.15 & 0.43 & 0.20 & 0.12 & 0\\ 0.23 & 0.31 & 0.18 & 0.15 & 0\\ 0.30 & 0.41 & 0.15 & 0.12 & 0.02\\ 0.15 & 0.20 & 0.33 & 0.26 & 0.07\end{pmatrix}$$

(4) Define factor domain of discourse factors weights. Then it has weight vector W, $W=(w_1,w_2,\cdots w_n)$, by analytic hierarchy process, it establishes judgment matrix to solve factors weights.

(1) Construct judgment matrix

u_i,u_j importance comparison structure is using a_{ij} to express, then all factors carry out comparison and then can get judgment matrix A. Its expression is as following.

$$A=\begin{pmatrix}a_{11} & a_{12} & \cdots & a_{1j}\\ a_{21} & a_{22} & \cdots & a_{2j}\\ \vdots & \vdots & \ddots & \vdots\\ a_{i1} & a_{i2} & \cdots & a_{ij}\end{pmatrix}$$

Among them, a_{ij} value is respective expressed by 1~9 numbers and their reciprocals, after Saaty researching, it is thought that using 1~9 scale to express comparison structure conforms to people judgment ability in psychology. Number respective expressive definitions are as following TABLE 2.

TABLE 2 : 1~9 scale meaning

Scale	Meaning
1	Indicates two factors have equal importance by comparing
3	Indicates the former is slightly more important than the later by comparing two factors
5	Indicates the former is more important than the later by comparing two factors
7	Indicates the former is relative more important than the later by comparing two factors
9	Indicates the former is extremely more important than the later by comparing two factors

Even number	Represents importance is between two odd numbers
Reciprocal	Represents factors positive and negative comparison orders.

(2) Consistency test and weight vector calculation

Judgment matrix consistency indicator CI, and judgment matrix consistency rate CR, its computational method is as following formula shows:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

Among them, n represents judgment matrix order number, that is also the number of comparison factors:

$$CR = \frac{CI}{RI}$$

Among them, RI represents Random Consistency Index value, as following TABLE 3 show.

TABLE 3 : RI value table

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

When $CR \geq 0.1$, it is thought that judgment matrix appear inconsistency. When $CR < 0.1$, judgment matrix inconsistency is within acceptance range, it can go ahead with next step calculation. Further calculate hierarchical total arrangement and combination consistency test.

Weight calculation. Calculate judgment matrix weight vector has many methods such as definition calculation, computer iteration, power method and harmonization method, from which the relative simple one is harmonization method. Assume judgment matrix An pieces of factors weight's weight vector is as following:

$$W = (w_1, w_2, w_3 \cdots w_n)$$

Then judgment matrix is expressed as following:

$$A = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{pmatrix}$$

According to above matrix property, it can stepwise, firstly make normalization on all column vectors of A and get matrix D:

$$D=\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \bullet \begin{pmatrix} 1/\sum_{i=1}^{n} a_{i1} & 0 & \cdots & 0 \\ 0 & 1/\sum_{i=1}^{n} a_{i2} & \cdots & 0 \\ 0 & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1/\sum_{i=1}^{n} a_{in} \end{pmatrix}$$

Solve matrix every line sum after normalization. It gets matrix E:

$$E = D \bullet \begin{pmatrix} 1 & 1 & \cdots & 1 \end{pmatrix}_{1\times n}^{T}$$

$$E = \begin{pmatrix} e_{11} & e_{12} & \cdots & e_{1n} \end{pmatrix}^{T}$$

Normalize matrix E that is weight vector:

$$W = \begin{pmatrix} w_1 & w_2 & \cdots & w_n \end{pmatrix} = \begin{pmatrix} e_{11}/\sum_{i=1}^{n} e_{i1} & e_{12}/\sum_{i=1}^{n} e_{i1} & \cdots & e_{1n}/\sum_{i=1}^{n} e_{i1} \end{pmatrix}$$

Calculate maximum feature value:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(AW)_i}{w_i}$$

(3) Weight vector result

By above methods, construct judgment matrix as:

$$P=\begin{pmatrix} 1 & 2 & 1/2 & 3 & 1 & 5 \\ 1/2 & 1 & 1/3 & 2 & 1/2 & 3 \\ 2 & 3 & 1 & 6 & 2 & 8 \\ 1/3 & 1/2 & 1/6 & 1 & 1/4 & 1 \\ 1 & 2 & 1/2 & 4 & 1 & 4 \\ 1/5 & 1/3 & 1/8 & 1 & 1/4 & 1 \end{pmatrix}$$

$$W = \begin{pmatrix} 0.21 & 0.12 & 0.36 & 0.05 & 0.21 & 0.05 \end{pmatrix}$$

Maximum feature value :

$$\lambda_{\max} = 6.04$$

Consistency test ratios:

$$CR = 0.006 < 0.1$$

Calculation result passes consistency test.

Calculate and analyze result

By above methods calculation, it can get vector W, fuzzy matrix. Compose A and R by utilizing composite operator $M(\bullet,\oplus)$, it get vector $B=(b_1,b_2,\cdots b_m)$. Calculate scheme evaluation model, respectively calculate each scheme, finally compare and get relative reasonable scheme.

$$B_1 = WOR_1 = (0.21 \quad 0.12 \quad 0.36 \quad 0.05 \quad 0.21 \quad 0.05) O \begin{pmatrix} 0.16 & 0.42 & 0.23 & 0.12 & 0.07 \\ 0.54 & 0.21 & 0.16 & 0.09 & 0 \\ 0.53 & 0.23 & 0.14 & 0.10 & 0 \\ 0.13 & 0.19 & 0.44 & 0.18 & 0.06 \\ 0.35 & 0.30 & 0.15 & 0.19 & 0.01 \\ 0.30 & 0.12 & 0.30 & 0.1 & 0.08 \end{pmatrix}$$

Calculate and get:

$$B_1 = (0.38 \quad 0.28 \quad 0.19 \quad 0.13 \quad 0.02)$$

Similarly, it gets other schemes calculation results, relative data is as TABLE 4 shows:

TABLE 4 : Calculation result

Target	Indicator criterion	Weights	Strategy	Evaluation result
Architectural lighting design's energy saving research	Illumination	0.21	Plan architecture overall layout	Very effective
	Daylight Factors	0.12		
	Useful Daylight Illuminance	0.36	Optimize architectural form	Very effective
	Daylight Autonomy	0.05		
	Continuous Daylight Autonomy	0.21	Reasonable daylight opening shape and materials design	Relative effective
	Annual Light Exposure	0.05		

$$B_2 = (0.36 \quad 0.24 \quad 0.20 \quad 0.13 \quad 0.03)$$

$$B_3 = (0.21 \quad 0.41 \quad 0.24 \quad 0.09 \quad 0.01)$$

CONCLUSION

According to fuzzy mathematics maximum membership principle, three strategies evaluation are all in the grade of relative effective and above. Among them, highest scores is plan architectural overall layout, secondly is optimize architectural form. Therefore, when researching on architectural lighting relative energy saving problems, it should firstly according to local region climatic environment, consider civil architectural overall planning layout, on a whole, ensure combination of lighting and energy saving. Secondly research on architectural form design, finally is daylight opening relative design.

Similarly when designing architecture, considering lighting standards take useful daylight illuminance weights as maximum, which should focus on considering. Secondly are illumination and continuous daylight autonomy and other indicators. Integrate indicators factors and strategy schemes' evaluation results to consider civil architectural lighting design's energy consumption problem.

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