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Research on Building Energy Efficiency Management and Index Evaluation System

Peiwei Xu*[a], Yue Xu[b], Naiyan Zhan[b], Can Li[b], Haijiang Lu[b]

[a]Jilin HuaHan culture co., LTD
[b]School of Municipal And Environment Engineering Department, Jilin jianzhu University, Jilin, China
velon0066@sina.com

Building energy efficiency and index evaluation system was not only the important key to decide whether a building was energy saving or not but also method of the result of the evaluation system. By analyzed a large number of representative data and relied on the theory analysis, investigation on the spot, simulation, experimental test and expert evaluation, a complete set of scientific evaluation system, evaluation method and quantified evaluation index coulD be established. At the same time, it could be found why the building energy efficiency was low. That might offer the scientific basis to the policy of the building energy efficiency, and also provided the technical consulting, technical training, design of system and construction for the society and users. It could brighten the future of the evaluation system in China.

1. Introduction

Nowadays, China has become the biggest energy consumption country in the world, and the amount of buildings' energy consumption is increasing each year. Every year, the area of the new buildings occupy 1.7 to 1.8 billion square meters, which is more than the sum of the each year's completed buildings' area in developed countries. However, among the completed buildings, the area is 40 billion square meters, but the percentage of energy saving building is only 1%. And each year, the truly energy saving buildings are no more than 100 million square meters, which is confirmed (Xiangyun Mou (2014)). The percentage of the building consumption rise from 10% in late 1970s to 27% in this year. Juaner Zheng, Cifang Wu (2005) reported the heating energy consumption in unit building is twice or three times as much as those in the developed countries where the climate is similar to China. In another word, building energy wasting is extremely serious. According to experts' statistics, the potential market of renovation and upgrade in building energy saving in our country is more than 100 million, while the north has greater potential. But our building energy assessment work is still in the qualitative analysis phase, it rarely has accurate basic data of building energy consumption, not even mention about an efficient system of evaluating building energy saving performance and degree. According to *'the Twelfth Five-Year Plan' Comprehensive Energy Conservation Program of Work* (2011) , it calls for 'Improving energy saving statistics and monitoring and evaluation system'' Accelerating the promotion and application of energy saving technology, establishing technical selection, evaluation and promotion mechanisms'.

2. Core framework

Hongxia Wei (2006) reported that the factors that influence the effect of building energy efficiency are countless, so it should chose some most refined indicators to reflect the most important and comprehensive information on the evaluation index selection. By studying on American LEED, British BREEAM, Canadian GBTool, Japanese CASBEE and Chinese *Green Building Evaluation Criteria* (2006), it shows that though the index and the focus of every evaluation system are different, they all choose the multi-level weighting system to analysis, at the same time, each index is apparent affiliation. So the building energy efficiency system in cold area adopt the tower structure, which means, a higher index gets score from the lower' weight summing up, the method possesses sustainability, which is confirmed (Guiyong Yan, Junqi Yu and Jing Gao (2013)). According to the basis of the current energy efficiency criteria in China and north-east area, acceptance of construction quality energy-saving projects and mandatory or important provisions building evaluation criteria, residential buildings and public buildings can be determined after the argumentation among the experts. The

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New Building is named when the building meet the requirements of Jilin province's *Residential building design standards (energy saving 65%)* (DB22/T450-2007) and *Public buildings design standards* (DB22/436-2007), others are defined as Existing Building. The residential buildings are divided into four classes, according to the *Severe cold and cold area residential building energy-saving design standards* (JGJ26-2010), the residential buildings can divided into for classes: less than 3 stories, 4~8 stories, 9~13 stories and more than 14 stories, and according to *Public Building energy-saving Design Standards* be divided the new and the exist public buildings into two classes: class A building and class B building. The framework is shown in Figure 1.

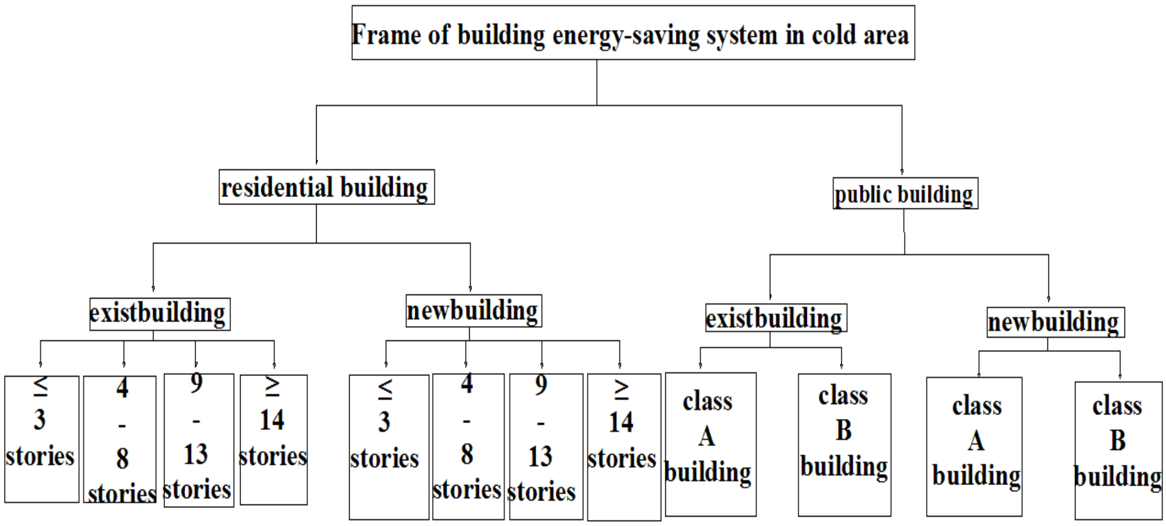

Figure 1: Type classify in cold area

3. Evaluation of system approach

Xudong Chen (2005) reported the building energy-saving analysis is a complex and intricate process, a thinking method and skill measures, which decomposes a complex objection into some simple factors. Every index may have some condition that cannot be estimated. Some index can be counted while others not. If considering the property of index, the index of evaluation can be divided into two types, qualitative indicators and quantitative indicators. Judging by the differences between the two indicators, building energy-saving evaluation can divided into two phases, qualitative phase and quantitative phase. The study on the whole analysis of building energy-saving is the unity of qualitative and quantitative, which is conformed (Zhifeng Chen (2006)).

The qualitative analysis is the characteristic description about characteristic, situation and problem. It can obtain a thinking process on tendency judgment through theoretical and experimental reasoning. The quantitative analysis is the thinking process about judgment and quantitative relationship by means of corresponding mathematical model and index or criteria, aiming at experimental results.

4. The index calculation method

4.1 Weight settings

4.1.1 Qualitative indicators weight settings

Zhifeng Chen (2006) reported that qualitative indicators weighing adopts Delphi method, a feedback anonymous letter inquiry method, which means using inquiry from letter to communicate. It is representative, air and more reliable than other methods. The process of the first step is collecting the information from experts, senior staffs, some corresponding departments in government, researchers, skilled workers and ordinary people, and the second step is organizing, summarizing and counting the information, the third step is feeding back the information to consultants, the fourth is asking for opinions again, collecting opinions again and feeding back opinions again till the consensus reach an agreement.

4.1.2 Quantitative indicators weight settings

Quantitative indicators weighing adopts simulation and experimental methods. On the one hand, using heat flow meter and temperature control box-heat flow meter to test, choosing some representative buildings whose floors are less than seven and more than seven as well as some public buildings to test, on the other hand, setting up mathematical model to simulate. DeST and Tianzheng can check the result in order to insure the accuracy. By comparing the experimental results and simulation results, final the result is obtained.

4.2 Method of qualitative evaluation phase

Qualitative evaluation phase is the first phase. It is the check and confine of buildings' necessary conditions. This phase carries on the energy-saving evaluation on the basis of designing materials, construction materials and details of construction in building as well as measure of energy-saving.

4.2.1 Determining the qualitative indicators

In the cold region of China, the residential building now takes measure of controlling shape coefficient and the radio of window to wall to save energy, adopting the new wall materials just as aerated concrete block to heat preservation, adopting small thermal conductivity composite materials and double or triple energy efficient insulation windows and doors to keep the external structure warmer. The indoor thermal environment quality will be better with above measures of reducing the heat dissipation, which is confirmed (Jinrong Zhang (2012)). There are five indicators to determine the qualitative indicators, it concludes heat transfer coefficient, radio of window to wall, shape coefficient, building and external structure and indoor heat system.

4.2.2 Method of qualitative evaluation phase

According to country's and north-east area's criteria, standards and mandatory or important clause about energy-saving, the second indicator can separated into three levels. Those are ten point, six point and zero. The second indicator gets the points when it meets the requirement. The buildings can get final point through score multiply the weight on the basis of the weight of second indicator.

4.3 Method of quantitative evaluation phase

4.3.1 Determining the quantitative indicators

The residential building quantitative phase indicators in cold area should meet these two requirements. Firstly, it should be representative and can be applied for geographical features in cold areas, taking protection against the bitter cold in winter into consideration and also meets the requirement of keeping the antifreeze. Secondly, it must be operable. With the support of modern technology, it can easily operate experiment test and mathematical modeling in order to insure the accuracy of data, at the same time, energy-saving system should be easily operated and learned. To meet these requirements, we can refine four indicators among many factors. Those are wall, window, roof and the cold air infiltration.

4.3.2 Method of quantitative evaluation phase

The method of quantitative evaluation is proportion of summation, progressively one by one to score. The 8 is the basic (standard building), the max point is 10 and the minimum is 0. If a building's score is higher than 10, the score is 10; When one's score is lower than 0, the score is 0. According to the indicators' weight, summation of score multiply the weight, the score of a building can be listed. And then classify their level on the basis of score. The concrete scoring method is as follows:

*Standard building: every indicator meets the standard of country's energy saving

The formula as follows:

$$\theta_i = \frac{Q_i' - Q_i}{Q_i} \qquad (i = 1, \cdots, 4)$$

where θ_i is the mean value of the actual radio coefficient of energy consumption and Q_i is the mean value of the The first level indicator consumption of meet the requirement, Q'_i is the the building's indicator consumption. Use *italic symbols* for quantities and variables. Punctuate equations with commas or periods when they are part of a sentence.

*Actual radio coefficient of energy consumption (θ_i)is the basis of getting score, the definition is the radio of the standard building first level indicators consumption and the difference between the building ready to score and the standard building.

$$T_i = 8 \times (1 - \theta_i)$$

$$T = \sum_{i=1}^{4} \eta_i T_i \qquad (i = 1, \cdots, 4)$$

where T_i is the mean value of the score of first level indicator and T is the mean value of the final score, η_i is the first indicator weight.

5. Method of system score

Building energy-saving system can be divided into two phases, one is scoring for the qualitative indicator, called the first phase; the other one is scoring for the quantitative indicator, called the second phase. In the qualitative phase, the buildings whose score are more than 6 can go into the quantitative phase. The buildings whose score are 6 or less than 6, the buildings' energy-saving evaluation are over or goes into the diagnostic phase. The details are listed in Table 1.

Table 1: Level standard of qualitative evaluation

Qualitative evaluation phase score	Result of evaluation
T>6	Go into quantitative phase
T≤6	Building's energy-saving evaluation is over or go into the diagnostic phase

Buildings which can go into the evaluation phase, by calculating the qualitative indicators, score final point T and take T as the standard of separation of building energy-saving. Results are described in Table 2.

Table 2: Level standard of building energy-saving evaluation

Score of phase in quantitative evaluation	Level of building energy-saving
T≥7.5	★★★
6≤T<7.5	★★
4≤T<6	★
T<4	No level and go into optimizing phase

6. Case analysis

In order to insure the feasibility of the method, now analysis a building in Changchun in Jilin province.

Table 3: Case study

Position	Changchun, Jilin province	Type	Multistory residential area	Age	3 years
Background of building	Material of construction and design are complete and mutual the same: the whole and the details of structure of the building meets the requirement of building energy-saving.				
Evaluation of the situation	1.Test on building in November 2013 2.Set up mathematical model and simulate from November 2013 to January 2014				
Qualitative Indicator					
	First level indicator		Simulation		
Qualitative indicator	Process is omitted				
Quantitative Indicator					

Quantitative indicator	First level indicator	Actual energy consumption radio coefficient calculation.	Indicator score calculation
	Wall	$\theta 1 = \frac{Q'1 - Q1}{Q1} = \frac{20995 - 22064}{22064} = -0.048$	T_1=8×(1-θ_1)=8×[1-(-0.048)]=8.384
	Window	$\theta 2 = \frac{Q'2 - Q2}{Q2} = \frac{40993 - 36654.4}{36654.4} = 0.12$	T_1=8×(1-θ_2)=8×(1-0.12)=7.04
	Roof	$\theta 3 = \frac{Q'3 - Q3}{Q3} = \frac{7151 - 7794}{7794} = -0.077$	T_1=8×(1-θ_3)=8×[1-(-0.077)]=8.616
	The cold air infiltration	$\theta 4 = \frac{Q'4 - Q4}{Q4} = \frac{7616 - 6947.1}{6947.1} = 0.096$	T_1=8×(1-θ_4)=8×(1-0.096)=7.232
	The total score	Weight coefficient of wall is 0.29. Weight coefficient of window is 0.52. Weight coefficient of roof is 0.10. Weight coefficient of the cold air infiltration is 0.09. $T = \sum_{i=1}^{4} \eta i \mathrm{T} i = 0.29 \times 8.384 + 0.52 \times 7.04 + 0.10 \times 8.616 + 0.09 \times 7.232 = 7.60$	
	Level energy-saving	T=7.60>7.5 is the ★★★ energy-saving building	

7. Conclusion

Through applying the system of building energy-saving evaluation, it can test and evaluate the building all-around and multilevel, not only completing the level test also diagnosing why the building is not energy-saving. At the same time, the system plays an important role in perfecting the effect. During the 'twelfth five-year', it also can have some influence on building energy-saving evaluation in north cold area. After establishing this evaluation, the building evaluation system can be set in other area in China, which in order to satisfying the different demand and adapting the different situation. Thus, the building evaluation system can be from specific to general, and may brighten the future development in building energy efficiency.

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