Rural vitalization-oriented suitability evaluation index for green technologies of rural housing in Northeast China

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Abstract. The Chinese government attaches great importance to the issue of agriculture, rural people and rural areas. After nearly twenty years, the living environment of farmers has been initially improved. However, there are still problems of uneven development and environmental pollution of some areas. For this reason, China has put forward the strategy of rural vitalization, aiming at solving the problems above. With this opportunity, it is feasible to develop green houses in rural areas. Taking the rural housing in Northeast China as an example, this paper analyses rural housing present situation there. The concept of suitability for green building technologies is raised. Based on this, the index system of suitability evaluation of green building technologies for residential buildings in northeast rural areas is established. It provides strategies for the government to promote green rural housing.

1. Introduction
The Chinese government has always focused on solving the issues relating to agriculture, rural areas, and rural people. Since Eleventh Five-Year period, laws and regulations have been promulgated to improve the living environment of farmers. In recent years, some achievements have been made, but there are still some problems. The situation of living environment in China is very uneven, and the problem of dirty and messy is still prominent in some areas. There is gap between unbalanced and inadequate development and the people’s ever-growing needs for a better life. In February 2018, Three-Year-Action Plan for the Improvement of Rural Residential Environment was released to push rural work to a new stage. How to build green rural housing is one of the key points of the Plan. This paper analyses the suitable technologies features and discusses the evaluation index system for green residential buildings.

2. Literature review
The rural housing in Europe and America is different from that in rural areas in China. First of all, the municipal pipe network supporting system in western countries is perfect. There is no difference from the city's municipal conditions. Secondly, the economic conditions of urban and rural areas are not very different. In some suburbs, the housing conditions are better than those in the city. Most rural houses in China do not have centralized drainage system. The rural economic conditions are backward. The construction level of the building is backward. Many green building technologies are not suitable for rural development. Jin and Ling Aiming at low cost, low technology and low energy consumption, the strategy of rural residential design in cold regions is put forward [1]. Aiming at low cost, low
technology and low energy consumption, the strategy of rural residential design in cold regions is put forward. The thermal performance of the straw plate - steel structure is studied. According to the characteristics and conditions of rural construction, scholars have studied the specific technical problems of architectural design strategy [2], enclosure structure [3,4] and heating and cooking equipment optimization [5]. According to the status of village building construction in cold regions, combining the six elements of total quality management, Chi et al analysed application suitability of reinforced concrete block masonry in villages in cold region. An evaluation method for application suitability of reinforced masonry block masonry structures in severe cold regions was proposed. Based on the theory of ecological footprint, Ling et al [6] proposed the optimization method of rural residential envelope.

3. The state of rural residential building
Northern rural housing is mainly independent building of one or two floors. Rural housings in plain areas are generally centralized, while in hills, mountains and highlands, they are relatively scattered. The floor area is generally 80 to 150 m², the per capita building area is 20 to 40 m², and the courtyard area is 200 to 500 m². With the improvement of rural economic conditions, farmers have more funds to improve living condition. But the wrong value of the bigger the better would result in loss of farmland and great waste of resources. The envelope construction determines the thermal performance of building, which is important factor for northern house in winter. According to the survey, brick wall accounts for 67.08% (table 1), and wood window accounts for 73.87% (table 2). There is no effective thermal insulation measure adopted in roof and floor.

| Table 1. Type of wall of rural housing. |
|----------------------------------------|
| Brick wall | Clay wall | Brick-Clay wall | Stone-Clay wall | Brick-Stone wall | Others |
|-----------|-----------|-----------------|----------------|-----------------|--------|
| 67.08%    | 17.41%    | 12.71%          | 5.37%          | 2.23%           | 0.46%  |

| Table 2. Type of window of rural housing. |
|------------------------------------------|
| Wood window | Steel window | Plastic-steel window | Others |
|------------|--------------|----------------------|--------|
| 73.87%     | 16.42%       | 7.98%                | 1.71%  |

3.1. Site plan and architecture design
There is no site plan and architecture design for most rural building. People in countryside build house by neighbours and themselves. Functional partitioning is not reasonable. Traffic routes cross each other [7].

3.2. Envelope structure
The building wall material is single. Solid clay bricks are commonly used on exterior walls. The use of new wall materials is extremely low. The thermal insulation performance of envelope is generally poor.

3.3. Energy using equipment
Rural housing heating is mostly local heating facilities such as Kang and stoves. The equipment is simple and the thermal efficiency is low. The heating system design and piping layout are unreasonable, resulting in energy waste and poor system circulation.

3.4. Indoor environment
Rural buildings have low indoor temperatures in winter and poor living comfort condition. Indoor pollution is serious. Indoor temperature fluctuates dramatically.
4. Establishment of suitability evaluation index

4.1. Definition of suitability of green building technology
The connotation of appropriate technology is determined by the combination of ecological environment, climate, cultural traditions, technological and economic conditions and other factors in different regions, and technology adapted to specific regions. The choice of technology is based on local acceptance [8]. The combination and form of technology will be changed according to the local society, economy, environment, and resources, etc.

4.2. Evaluation objects
The existing green building assessment standards are the references of rural green building. Table 3 displays indicators of LEED, BREEM, and GBL. They are ranked by weightings. All of them contain the aspects of energy, material, water, land and indoor environmental quality, which are the categories of the existing green technologies for rural residential buildings. The evaluation objects contain energy-saving technologies, water-saving technologies, land-saving technologies, materials-saving technologies, and indoor environmental improve technologies.

Table 3. Indicators of LEED, BREEM and GBL.

| LEED (US.)                  | BREEM (UK.)               | GBL (China)               |
|-----------------------------|---------------------------|---------------------------|
| 1. Energy and Atmosphere    | Energy                    | Energy Saving             |
| 2. Location and Transportation | Health and Wellbeing     | Material Saving           |
| 3. Indoor Environment Quality | Materials                | Indoor Environmental Quality |
| 4. Materials and Resources  | Land Use and Ecology      | Water Saving              |
| 5. Water Efficiency         | Management                | Land Saving               |
| 6. Sustainable Site         | Transport                 |                           |
| 7. Innovation               | Pollution                 |                           |
| 8. Regional Priority        | Water                     |                           |
| 9. Integrative Process      | Waste                     |                           |
| 10                          |                           | Innovation                |

4.3. Evaluation methods
The evaluation methods with different characteristics are displayed in table 4. The assessment objects belong to different areas. Their importance couldn’t be compared directly. The assessment objects and the assessment aim determine that Analytic Hierarchy Process (AHP) is suitable to use.

Table 4. Assessment methods.

| Methods                     | Characteristic                                                                 |
|-----------------------------|-------------------------------------------------------------------------------|
| Fuzzy Evaluation Method     | On the basis of fuzzy mathematics, fuzzy language is used to determine the membership grade of every index of things, and some indexes which are unclear and unquantitative are graded. Then the principle of fuzzy relation synthesis is applied to determine the comprehensive membership degree of the objects to each grade [9]. |
| Analytic Hierarchy Process  | A complex problem is decomposed into various components, and the structure of the hierarchical layer is formed according to the order of |
the total target, the sub target, the evaluation standard and the specific measure, and the relative importance of the factors in the hierarchy is determined by pairwise comparison. Then, using the method of determining the eigenvector of the matrix, the relative weight of each element on the upper level is obtained. Finally, the weight of the weighted sum method is used to calculate the weight of the total target [10].

Optimization Theory

The optimization decision of independent scheme is to establish several optimization objective functions based on different construction targets. The optimization decision between independent schemes refers to seeking the optimal combination of schemes under a series of constraints in many independent schemes to determine the details of each scheme [11].

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**Figure 1.** Suitability evaluation index for green technologies of rural housing in northeast China.
4.4. Evaluation indicators
On the basis of definition of suitability of technology for green building particularly in rural area, which is different from that in urban, the evaluation indicators include economic factors, technical availability factors, performance factors, and regional factors. The Primary indicators is made up of these 4 factors (figure 1).

4.4.1. Economic factors. In northeast china, the economy of rural area is backward. The income of peasant family is lower than the average level of whole country. In figure 2, Inner Mongolia, Liaoning, Jilin, and Heilongjiang cover the area of northeast of China. The annual family income is fall behind the other province, and it is the half of urban income average value. It influents the green building technology cost which is affordable for family there. Before the economic condition is improved, the choice of green technology for northeast rural building is sensitive to the cost. Evaluation of a technology applied in the area of economic suitability, the return of technology investment or regional economic level are not the only criterion. The technology of return on investment and regional support capacity should combined together. Where the economy is relatively backward, technology with a longer investment return cycle is not good choice. Secondary indexes of economic suitability are investment recovery period and the proportion of investment in annual income. Table 5 shows northeast area rural family annual income.

![Figure 2. Anual income of rural family in 2016 of different province.](image)

| Table 5. Northeast area rural family annual income. |
|-----------------|----------------------------------|
| Location        | Rural family annual income/yuan/family |
| Inner Mongolia  | 11609                             |
| Liaoning        | 12880.7                           |
| Jilin           | 12122.9                           |
| Heilongjiang    | 11831.9                           |

Investment recovery period can be described by static payback period (the formula 1~3).

\[ P_i = \frac{\Delta B}{\Delta C} \]  \hspace{1cm} (1)

\[ \Delta B = \Delta A \times C + \Delta A \times f \times C_c \]  \hspace{1cm} (2)

\[ \Delta C = C_n - C_0 \]  \hspace{1cm} (2)
In the formulas:
\( P_j \): Static investment payback period, (year);
\( \Delta B \): The overall benefits of technology, (yuan);
\( \Delta C \): Increase in cost, (yuan);
\( \Delta A \): The amount of standard coal equivalent (ton) or power consumption (degree) saved after the implementation of green building technology each year;
\( C \): Local raw coal price or electricity price. The price of raw coal in different regions of China is about 800–1200 yuan/ton (average value 1000 yuan/ton). Electricity price is 0.5–0.6 yuan/degree (average value 0.55 yuan/degree). 1 ton raw coal converts to 0.7143 t standard coal. 1 electricity converts to 0.404 t standard coal.
\( f \): Raw coal emission factor GHG 0.7559 kg(C)/kg (standard coal) (IPCC National Greenhouse Gas Emission Inventory Guide). Emission factor GHG for purchasing electricity 0.623kg/kW·h.
\( C_c \): Price of carbon sequestration, 230.7 yuan/t.
\( C_n \): Construction cost of energy efficient building in rural areas after application of green building technology, (yuan).
\( C_0 \): Construction costs of conventional rural construction methods, (yuan).

4.4.2. Technical availability factors. As pointed above, construction pattern of rural building is unprofessional. Most parts of project depend on neighbourhood help by each other. The complex technologies aren’t suitable to use here. The low technologies are preferred. Besides, technical availability is related with construction cost. The indexes of equipment, material, operation procedure, and number of constructors could be used to evaluate technical availability factors (table 6).

**Table 6. Secondary index of technical availability factor.**

| Secondary index      | Explanation                          |
|----------------------|--------------------------------------|
| Equipment            | Is complex mechanical equipment needed? |
| Material             | Are building materials available in local or nearby areas? |
| Operating procedure  | Is the construction procedure complicated |
| Number of constructors | How many builders do you need?        |

4.4.3. Performance factors. The aim of technology application is to build green house for rural people. According to connotation of green building, the comfortable living condition is created based on the minimum influence on nature environment. The technologies with high performance would make the green building goal be realized. In this part, some values are the index of technologies, which are displayed in tables 7-9.

**Table 7. Secondary index of energy saving performance factor.**

| Secondary index        | Explanation                                                                 |
|------------------------|-----------------------------------------------------------------------------|
| Envelope performance   | Heat transfer coefficient of building envelope                              |
| Renewable energy use   | How much kilowatt-hours are the amount of renewable energy                   |
| Energy consumption     | How much energy does energy efficient equipment save in heating, cooling,   |
| equipment              | cooking, lighting, entertaining, studying, and working?                     |
| Passive design         | How much energy do the passive design technologies save?                    |
Table 8. Secondary index of indoor environmental quality performance factor.

| Secondary index                            | Explanation                                      |
|--------------------------------------------|-------------------------------------------------|
| Sound environment                          | Noise isolation effect                          |
| Light environment                          | Room view                                       |
| thermal and humid environment              | Daylight factor                                 |
| thermal and humid environment              | Relative humidity of indoor air                 |
| thermal and humid environment              | Indoor air temperature and its distribution     |
| Air quality                                | fresh air volume                                |
| Air quality                                | Air pollutant concentration                     |

Table 9. Secondary index of water saving factor, land saving factor, and material saving factor.

| Secondary index | Explanation                                      |
|-----------------|-------------------------------------------------|
| Water saving    | The amount of water saved by the technologies   |
| Land saving     | The amount of land saved by the technologies    |
| Material saving | The amount of material saved by the technologies|

4.4.4. Regional factors. Regional factors reflect the principle of adapting to local conditions. Building materials are advocated on the basis of local materials. From the perspective of LCA, it can reduce transportation energy consumption and reflect the local architectural culture. Building structures meet the needs of local climate and environment.

4.5. Evaluation index weight

Weight is a measure that compares and balances the relative importance of various factors in the evaluated object. AHP mainly includes two aspects. First, build a hierarchical model. Secondly, determine the relative weight of each element under a single criterion and the combined weight of the target layer. The three-scale method (i.e., the 0, 1, 2 scale method) determines the weight of each indicator. 0 means that one factor is not as important as the other. 1 means that two factors are just as important. 2 indicates that one factor is more important than the other. The index matrix is obtained through the expert questionnaire. Finally, the eigenvector of the consistency judgment matrix is obtained. The approximate value of eigenvectors is calculated by multiplicative square root method.

5. Conclusion

This paper discusses the green technology suitability evaluation index of rural housing under the strategy of rural revitalization. First, the current situation of rural housing in Northeast China is described, including site plan, architecture design, building envelope, energy consumption equipment and indoor environment. Secondly, the definition of suitability of green building is put forward. Third, according to the comparison of the green building assessment standards, the scope of the evaluation object is pointed out. They are energy saving technology, water saving technology, land saving technology, material saving technology and indoor environmental improving technology. Fourth, several evaluation methods being compared, AHP is selected as evaluation method according to the characteristics of assessment objects. Finally, based on the research results above, the primary and secondary evaluation indicators are confirmed. According to the results of the expert questionnaire, the weight of the index is clearly defined. Rural vitalization needs to create a comfortable living environment for farmers. It is necessary to develop green rural housing. The research results provide a
method for the choice of green building technology in rural areas.

References
[1] Jin H and Ling W 2010 Low energy consumption, low-tech and low cost: Study on the design for rural energy-saving housing in cold region Archi. J. 2010 14-6
[2] Qu Y 2014 Research on key technology of suitability energy efficiency for buildings in rural area of Shanghai Building Science 30 120-5
[3] Gu W, Wang S and Yang S 2017 Research on dynamic behaviour of rural AAC buildings with base-isolated system Value Eng. 36 128-30
[4] Cao W, Zhang Y, Dong H, et al 2015 Research and application on aseismic energy-saving structural system for rural buildings Eng. Mech. 32 1-12
[5] Cao H, Gao Z, Han Y, et al 2015 Research on wind-absorbing energy-saving stove technology of rural buildings Construction Tech. Sci. 2015 142-3
[6] Jin H and Ling W 2012 Study on optimization of external wall structure of rural houses in Northeast China Building Science 28 10-3
[7] Zhu S and He M 2017 Ecological design strategy and appropriate technology of rural housing in eastern area of Hebei Province Building Energy Efficiency 45 29-31
[8] Ma D 2014 Research on green rural house technical guidance in Shandong District (Jinan: Shandong Jianzhu University)
[9] Li S 2004 Engineering Fuzzy Mathematics and Its Application (Harbin: Harbin Institute of Technology Press)
[10] Bruce L G, Edward A W and Harker P 1989 The Analytic Hierarchy Process: Applications and Studies (New York: Springer-Verlag Berlin Heidelberg)
[11] Chong P, Zak S, Sun Z et al (interpret) 2015 Introduction of Optimization (Beijing: Electronic Industry Press)