Research on relationship among driving elements of spatial heterogeneity for China’s green building

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Abstract. This paper summarizes the driving elements affecting the spatial heterogeneity of green building development through literature research and expert interviews. Based on the Interpretative Structural Model (ISM) and Decision-Making Trial and Evaluation Laboratory (DEMATEL). A multi-level hierarchical interpretation structure model is established. Through the analysis of centrality, cause and comprehensive influence degree, the interaction mechanism between driving elements is explored to provide decision-making basis for promoting the industrialization of green building. The result shows that Economic Development (P6) and Government Support and Regulatory role (P1) are the underlying elements in the model. The key layer elements in the model are laws and regulations (P2) and market demand (P3). The Core Layer Elements are the level of construction industry (P7), the support level of supporting industries (P8) and the technical level of professional personnel (P10). Industrial Technology Innovation Alliance (P4), Social Recognition (P5) and Industrial Chain Completion (P9) are the top elements in the model.

1. Introduction

Green buildings play an important role in reducing energy consumption, protecting the ecological environment[1]. The development of green building industry is another emerging industry derivative that is fostered in the innovation-driven environment[2]. In recent years, the development of the green building industry has been highly praised by China’s government[3]. In particular, the “Green Building Action Plan” in 2013 and the “Urbanization Conference” in 2016 paid great attention to the development of green buildings. Green buildings have become an important part in the development of China's construction industry. At present, the research shows that the development of green buildings is developing from single to industrial scale[4]. The “Implementation Opinions on Accelerating the Development of Green Buildings in China” officially proposed to achieve the goal of green buildings accounting for more than 30% of new buildings by 2020[5]. Yang Delin speculated that the total market size of China's green building industry will exceed 1 trillion RMB by 2020[6].

Green building has the characteristics of spatial distribution of industrial agglomeration, deeply analyzes the driving elements of regional heterogeneity in the development of green building industry, and analyzes the interaction mechanism between driving elements have important theoretical and practical significance for promoting the development of green building regional development[7].

2. Driving elements for spatial heterogeneity in the development of green building industry

The development of green building industry has a strong geographical distribution. At the same time,
the distribution of green building projects in different urban areas has a tendency to gather\textsuperscript{[8]}. Foreign scholars found that urban income levels, service industry development and the concentration of government institutions are the main element affecting the distribution of green buildings. Some scholars in China have done this work. Ye Zuda pointed out the spatial heterogeneity of green building industry development is closely related to the relevant policy implementation efficiency and local economic conditions\textsuperscript{[9]}. Zhang Wei found that the main elements of spatial heterogeneity in the green building industry are the urban economic aggregate and the administrative power of local governments, the administrative power of local governments is the dominant element\textsuperscript{[10]}. In summary, it can be found that scholars' research on the spatial distribution of the green building industry is still confusing. In this regard, on the basis of combing the literature, this paper combines industry research and interviews, expert consultation, data collection and analysis, summed up the dynamic elements of regional green building industry development differences, as shown in Table 1.

| No. | Element                                      | Explanation (phenomenon description)                                                                                                                                                                                                                     |
|-----|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P1  | Government support and regulatory role       | Green building industry development planning, design layout, market supervision and other operations require government support to guide and supervise, and its regional differences are significant.                                                                 |
| P2  | Law and regulation                           | The more perfect the laws and regulations, the clearer the implementation rules and evaluation criteria, and the guiding role for the development of green buildings will be more prominent.                                                                  |
| P3  | Market demand level                          | The level of urbanization in the region and the market demand of residents are the driving force.                                                                                                                                                    |
| P4  | Industrial technology innovation             | The core technology-related alliances related to green buildings, including the extensive cooperation between supporting equipment companies, general contract subcontractors, and research institutes.                                           |
| P5  | Social recognition                           | The use of new materials, new energy and new technologies for energy saving and environmental protection is not universal. The higher the level of local social cognition, the easier it is to accept green buildings. |
| P6  | The level of economic development            | According to statistics, most of the green building evaluation and identification projects are concentrated in economically developed areas. The fixed construction investment is different in different economic development areas. |
| P7  | Industrialization level of construction      | Reflecting the level of production methods, the higher the level of industrial production, the greater the capacity of large-scale industrialized production of green buildings, and the benefits of economies of scale are more likely to occur. |
| P8  | Support level of supporting industries       | The development of green building industry covers technical service level, social service level and financial industry support.                                                                                                                          |
| P9  | Industry chain perfection                    | The degree of in-depth cooperation between consulting design, technology development, construction, and operation management.                                                                                                                               |
| P10 | Professional talent team technical level     | The development of the green building industry started later than other countries. The level of professional talents, talent training and technical training are still quite different.                                                                               |
3. Integrating DEMATEL and ISM to analyze the relationship between the driving elements of green building industry regional development

Using DEMATEL and ISM to divide the system hierarchy, reveal the interaction mechanism between complex system elements and identify the key elements[11-13].

(1) The degree of influence between each driving element and the calculation of the direct influence matrix. According to the industry experts engaged in the development of green building industry, the five levels of influence are assigned 4, 3, 2, 1, 0, respectively. A total of 25 questionnaires were obtained. For the effective questionnaire survey results, the highest frequency is taken as the direct correlation degree of the driving elements, so as to construct the direct influence matrix

\[ X = \begin{bmatrix}
0 & 3 & 4 & 3 & 3 & 0 & 3 & 2 & 0 \\
4 & 0 & 0 & 3 & 3 & 0 & 1 & 2 & 4 & 1 \\
0 & 1 & 0 & 3 & 1 & 1 & 0 & 4 & 2 & 0 \\
0 & 0 & 0 & 0 & 3 & 0 & 4 & 2 & 4 & 1 \\
3 & 0 & 4 & 2 & 3 & 0 & 0 & 4 & 2 & 0 \\
0 & 0 & 4 & 2 & 3 & 0 & 4 & 1 & 4 & 1 \\
2 & 1 & 0 & 0 & 4 & 1 & 0 & 1 & 3 & 3 \\
0 & 0 & 0 & 4 & 0 & 3 & 0 & 4 & 1 & 3 \\
0 & 1 & 0 & 2 & 1 & 0 & 3 & 1 & 0 & 0 \\
0 & 0 & 0 & 3 & 1 & 0 & 4 & 0 & 3 & 0 
\end{bmatrix} \]

(2) The calculation normalization of directly affects the matrix \( G \) and the comprehensive influence matrix \( T \). To normalize the direct influence matrix, a matrix \( G = [g_{ij}]_{10 \times 10} \) can be obtained, \( g_{ij} \in [0, 1] \). The matrix \( T \) is used to represent the combined accumulation of direct and indirect effects to determine the final impact of each element on the highest level of elements in the system, \( T = G(I - G)^{-1} \), in the formula: \( I \) is the identity matrix.

(3) Calculation of influence degree, influenced degree, center degree and cause degree of each driving element. The integrated influence matrix \( T \) is added by column and row to obtain the influence degree \( e_i \) and the influenced degree \( f_i \), which are

\[ e_i = \sum_{j=1}^{10} t_{ij}, f_i = \sum_{j=1}^{10} t_{ij}. \]

Table 2. the influence degree, the influenced degree, center degree and cause of each driving element.

| Index | \( P_1 \) | \( P_2 \) | \( P_3 \) | \( P_4 \) | \( P_5 \) | \( P_6 \) | \( P_7 \) | \( P_8 \) | \( P_9 \) | \( P_{10} \) |
|-------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| \( e_i \) | 0.7959 | 0.5290 | 0.9250 | 1.9326 | 1.8014 | 0.2746 | 1.6891 | 1.5305 | 2.2199 | 0.7445 |
| \( f_i \) | 1.5507 | 1.5471 | 1.0410 | 1.1553 | 1.2010 | 1.7730 | 1.2923 | 1.2386 | 0.7232 | 0.9203 |
| \( m_i \) | 2.3466 | 2.0761 | 1.9660 | 3.0879 | 3.0024 | 2.0476 | 2.9814 | 2.7691 | 2.9431 | 1.6648 |
| \( n_i \) | -0.7548 | -1.0181 | -0.1160 | 0.7773 | 0.6004 | -1.4984 | 0.3968 | 0.2919 | 1.4967 | -0.1758 |

Figure 1. Center Degree - Cause Degree Cartesian Coordinate System.

The influence degree and the influenced degree of the driving elements are added to obtain the
centrality \( m_i = f_i + e_i \). The difference between the influence degree and the influenced degree of each driving element is the degree of cause \( n_i = f_i - e_i \). The calculation results are shown in Table 2. Taking the centrality as the abscissa and the cause as the ordinate, the Cartesian coordinate system of the green building industry development driving elements is drawn, as shown in Figure 1.

(4) Determine the overall influence matrix \( H \). Overall influence matrix can eliminate the influence of the driving elements on itself, and make the logical relationship analysis more reasonable.

(5) Determine the reachability matrix. Determine the reachability matrix \( R \) by \( H \),
\[
R = \begin{bmatrix} r_{ij} \end{bmatrix} \quad (i, j = 1, 2, \ldots, 10),
\]
\[
r_{ij} = \begin{cases} 1, & r_{ij} \geq \lambda \\ 0, & r_{ij} < \lambda \end{cases}
\]

(6) Determine the reachable set of each feature \( A \) and the set of the previous item collection \( B \). The calculation formulas are
\[
A_i = \{ x_i / x_j \in P, r_{ij} \neq 0 \},
\]
\[
B_i = \{ x_i / x_i \in P, r_{ij} = 0 \}.
\]

The reachable set of the first level and the set of the previous items are shown in Table 3.

### Table 3. The reachable set of the first level and the set of predecessors.

| Element | \( B(P_3) \) | \( A(P_3) \) | \( A(P_3)IB(P_3) \) |
|---------|--------------|--------------|---------------------|
| \( P_1 \) | 1,2,5,7 | 1,2,3,4,5,7,8,9 | 1,2,5,7 |
| \( P_2 \) | 1,2 | 1,2,4,5,7,8,9 | 1,2 |
| \( P_3 \) | 1,3,5,6 | 3,4,5,8,9 | 3,5 |
| \( P_4 \) | 1,2,3,4,5,6,7,8,9,10 | 4,5,7,8,9 | 4,5,7,8,9 |
| \( P_5 \) | 1,2,3,4,5,6,7,8,9,10 | 1,3,4,5,8,9 | 1,4,5,8,9 |
| \( P_6 \) | 6 | 3,4,5,6,7,8,9,10 | 6 |
| \( P_7 \) | 1,2,4,6,7,8,9,10 | 1,4,5,7,8,9,10 | 1,4,7,8,9,10 |
| \( P_8 \) | 1,2,3,4,5,6,7,8 | 4,5,7,8,9 | 4,5,7,8 |
| \( P_9 \) | 1,2,3,4,5,6,7,8,9,10 | 4,5,7,9 | 4,5,7,9 |
| \( P_{10} \) | 6,7,10 | 4,5,7,9,10 | 7,10 |

It can be seen from Table 3 that there is \( A(P_3)IB(P_3) \) with \( A(P_3)IB(P_3) \) so the element \( P_3 \) and \( P_9 \) are the most advanced element of the layer, then the first level indicator is \( \{P_3, P_9\} \), draw the reachable matrix \( R \), the rows and columns corresponding to \( P_3 \) and \( P_9 \) are obtained in the second level of the reachable set of pre-items. By analogy, the third, fourth indicator sets can be derived. On this basis, a multi-level hierarchical structure model of driving elements is constructed, as shown in figure 2.

![Figure 2. Multi-level hierarchical structure model of driving elements.](image-url)
development ($P_0$) and government support and supervision ($P_1$), both of which are causal elements, can have direct or indirect effects on other elements in different ways.

The government's role and economic development level are at the same level, which is the basic layer of spatial non-uniformity. At present, the government's support and supervision of green buildings is the most important driving element for the development of green building areas. It shows that the government plays a leading role; The degree of perfection of laws and regulations and the degree of market demand belong to the same level, which is the key layer of spatial non-uniformity. The establishment of a sound legal and regulatory mechanism is a key element in the development of green buildings[14]; The level of industrialization of buildings, the support level of auxiliary industries and the technical level of professional talents belong to the core layer of green building development. As green building is the transformation and upgrading development direction of the construction industry, they are important aspects of the development of the green building industry; The operation of the industrial technology innovation alliance, the degree of social recognition and the degree of industrial chain improvement belong to the highest level of green building development, they are the breakthroughs for the vigorous development of green buildings[15], also can promote the development of green buildings and realize industrialization and scale[16].

5. Conclusion
The paper uses the DEMATEL-ISM method to analyze the relationship between the driving elements of spatial heterogeneity in green building areas. The comprehensive influence matrix can analyze the mutual influence degree of each element, the status of each element and the relationship between the interaction mechanisms, so as to find out the basis for the development of spatial heterogeneity in green building area. In the future, research should focus on the development of technology research, industrial chain and green building society, and promote the in-depth promotion of green buildings.

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References
[1] Liu, Y., Guo, X., & Hu, F. (2014) Cost-benefit analysis on green building energy efficiency technology application: a case in china. Energy & Buildings, 82: 37-46.
[2] Liang, H., Zhang, F., & Liang, J. (2012) An important engine for china's economy to achieve green transformation: green building industry planning and development. Urban Development Studies, 10: 137-141.
[3] Wang, Y. (2013) Study on development trends of green buildings in china. Construction Technology, 42(11): 5-7.
[4] Li, Z., Wu, G. (2011) Evolution of green building and analysis of competitiveness for chinese green building industry. Journal of Guizhou University, 02: 50-54.
[5] Han, J., Du, Y., & Xu, R. (2012) The green building industry is accelerating in an all-round way: 30% of new buildings will be built by 2020. Architectural Design Management, 07: 77-77.
[6] Li, Z., Yang, D., & Wu, G. (2010) Green building forecast of a generation of leading industries. Enterprise Economy, 11: 18-20.
[7] Liang, J., Liang, H., Zhang, F., Bi, J., Liu, J., & Ma, X. (2012) Develop green building industry to lead green economy development. Construction Science and Technology, 17: 20-26.
[8] Chinese Green Building Evaluation Label. (2016) National Green Building Labeling Project Statistics. http://www.cngb.org.cn/.
[9] Ye, Z. (2012) Geographical distribution of urban green buildings in China. Modern Urban Research, 9: 42-48.
[10] Zhang, W. (2013) Research on Green Building Industry Agglomeration Based on Regional Comparative Advantage. Doctoral dissertation, Shanghai Normal University.
[11] Lundvall, B., & Freeman, C. (1988). Small countries facing the technological revolution. Industry & Higher Education, 11(1): 12-14.
[12] Qin, R., Wang, R., & Qin, X. (2014) The Hierarchy Structure and Key Elements Identification of the National System of Entrepreneurship: Based on the Integration of DEMATEL and ISM. Areal Research and Development, 33(6): 45-50.
[13] Wu, X., Huang, J., & Zhao, J. (2015) Analysis on Relationship among Developmental Problems of Offshore Engineering Equipment Industry Based on Integration of DEMATEL and ISM. Science and Technology Management Research, 4: 145-148.
[14] Liu, G., Li, X. (2014) Incentive Mechanism Design and Incentive Strength Research Based on Game Analysis for Green Building. Science and Technology Management Research, 34(4): 235-239.
[15] Ren, T. (2011) Vigorously developing industrial technology alliance is the breakthrough point for Xi'an to coordinate scientific and technological resources and enhance the core competitiveness of the industry. The Journal of Humanities, 2: 183-185.
[16] Lin, H., Wang, Q. (2014) Enhancing Technology Research and Promoting Scale Development of Green Building in China. Construction Technology, 43(10): 10-13.