Applied Energy Symposium 2019: Low carbon cities and urban energy systems
October 16-18, 2019, Xiamen, China
Paper ID: 0083

EVALUATION OF CHINA'S GREEN COMMERCIAL BUILDING INDUSTRY BASED ON ANP-SWOT MODEL

Kaile Zhou[1,2*], Rong Wang [1,2], Lulu Wen [1,2]

1 School of Management, Hefei University of Technology, Hefei 230009, China

2 Key Laboratory of Process Optimization and Intelligent Decision-making, Ministry of Education, Hefei University of Technology, Hefei 230009, China

ABSTRACT

Green building can effectively reduce building energy consumption and pollutant emissions. China has spent great efforts on developing green commercial buildings (GCBs). In this paper, we use the ANP-SWOT method to evaluate the development of GCBs in China. First, the SWOT matrix (Strengths, Weaknesses, Opportunities and Threats) was used to analyze the influence factors of the GCBs industry and to formulate alternative strategies. Then, the Analytical Network Process (ANP) methodology was utilized to establish a network structure and to calculate the weights of factors, sub-factors and strategies. Finally, based on strategies ranking, we drew the policy implications. The results showed that the insufficient economic incentives and inadequate attention are main factors curbing the development of China's GCBs and strengthening preferential policies and improving evaluation system are two more effective strategies of GCBs development in China.

Keywords: Green commercial building, ANP, SWOT, development strategy

1. INTRODUCTION

1.1 GCBs in China

GCBs can usually reduce operating costs and market risks while improving energy efficiency. GCB is featured by reasonable site planning and design, efficient recycling of resources, comprehensive and effective energy-saving measures, healthy and comfortable building environment, harmless and reduced waste, high performance and functional flexibility. The use of green roofs in Mediterranean climate can reduce the energy demand for heating and cooling by 6%-13% [1]. In tropics countries the light energy efficiency of green office buildings can reach 41% and 53% [2]. For Hong Kong's high-rise office buildings, about 78–89% of energy are consumed by building operation [3]. GCB could not only better satisfy people's physical and psychological needs, but also improve energy and environmental efficiency.

With the rapid development of economy, China is facing serious environmental problems. Commercial buildings, as an important carrier of commercial development, have developed rapidly in the domestic construction market. In order to achieve the synergistic benefits of reducing energy consumption and greenhouse gas emission, and promote the sustainable development of real estate industry, it is urgent to comprehensively evaluate and select determine the development strategy of GCB in China.

GCBs have the characteristics of large works quantity, long production cycle and high input cost. They also have problems such as insufficient specialization of the industry chain and imperfect industry standards. The function and operational benefits of GCBs projects also need be considered. Considering various factors affecting the development of GCBs, China need development more effective strategies conform to the characteristics of the whole industry.

1.2 ANP-SWOT model

SWOT analysis proposed by Kenneth Andrews, was used to solve problems of business strategy [4]. It is an important approach to analyze strategic management issues and provide support for decision-making. In the matrix analysis table, the corresponding factors are combined to obtain strategies, which are SO, ST, WO and WT combination. The factors affecting the development of GCBs involve various aspects. SWOT analysis was originally proposed to solve problems of enterprises [5]. In this paper, the application of SWOT analysis is extended from the enterprise to the development of the whole industry.

Saaty first proposed the analytic hierarchy process (AHP) and network ANP in 1980 and 1996 respectively [6]. ANP is a more general multi-criteria decision making method compared with AHP. However, the hierarchical structure in the AHP model does not work well when more complicated decision-making problem involves interdependencies among elements between and within model levels. The ANP method takes account of the feedback relation and the interdependencies among elements between and within model levels in the system. Therefore, ANP is revised to overcome the disadvantages of AHP.

Since the advantages of SWOT analysis and network analytic hierarchy process in dealing with the evaluation problem, Kantilla et al put forward the ANP-SWOT method model that combines the two methods [7]. The ANP-SWOT model can solve complex multi-factors decision-making problems and combine qualitative and quantitative analysis.

In this study, we use the ANP-SWOT model to evaluate the GCBs development in China. First, SWOT model identifies the influencing factors of the GCB industry development in China. In ANP structure, the development of GCB in China is the general goal of ANP model. The maximum eigenvalue $\lambda_{\max}$ and the corresponding eigenvector from the comparison matrix are calculated [8]. Finally, the maximum eigenvalue ω of the judgment matrix are summarized to obtain the weight values of each evaluation factor. The optimal strategy is the one with the largest weight value.

2. SWOT ANALYSIS

2.1 SWOT matrix and strategies

SWOT analysis matrix reflects the contributions of different influence factors. The strategies are obtained by matching the corresponding factors of the SWOT matrix, which shown in Table 1.

2.2 Strengths

2.2.1 Large construction scale

Commercial building has a variety of architecture types. Commercial buildings are the principal gathering places for social and production activities. Commercial buildings' types and project volumes are generally larger than that of other buildings.

2.2.2 Great energy saving potential

Compared with residential buildings, commercial buildings have significantly higher energy consumption and carbon emissions. Energy use per square meter in commercial buildings is over 3 times than that in residential buildings in Beijing and Shanghai [9]. Developing commercial building can achieve overall goal of energy saving and carbon reduction.

2.2.3 High economic efficiency

During operational period, consuming less resource

Table 1
SWOT matrix and strategies of GCB development.

	Strengths **S1** Large construction scale **S2** Great energy saving potential **S3** High economic efficiency	**Weaknesses** **W1** High investment cost **W2** Difficulties for technological applications **W3** Late and backward development **W4** Lack of rating and certificating systems
Opportunities **O1** Great demand in the construction market **O2** Enhancement of environmental protection awareness **O3** Government policy support	**SO Strategy** **SO1** Establishing diversified market and expanding scale **SO2** Learning benchmark building cases	**WO Strategy** **WO1** Technology promotion and innovation **WO2** Building the professional industrial chain
Threats **T1** Low cost of traditional building **T2** Weak initiative of practitioners **T3** Low acceptance for green building **T4** Insufficient government economic incentives	**ST Strategy** **ST1** Establishing corporate responsibility **ST2** Increase the market share **ST3** Satisfying the needs of consumers and market-orientation	**WT Strategy** **WT1** Strengthening economic incentives and preferential policies **WT2** Improving the green evaluation standard system

can save economic expenses. In an after-sales evaluation, the aggregate operating cost and cleaning cost, was 19% lower than average [10]. Although the property developers increase the additional cost by 1-12.5% for certification, the green price premium of certified buildings would be carried at 11-28% [11].

2.3 Weaknesses

2.3.1 High investment cost

Green buildings in China, compared with traditional buildings, cost higher in construction process by 10.9% [12]. Cost of silver-rated buildings certified by LEED range about 1-5% of the total infrastructure project cost [13]. The energy cost of green buildings accounts for 48% of the total cost. While there are differences in key barriers between developing and developed countries, the primary factor is higher initial costs.

2.3.2 Difficulties for technological applications

The current green technologies generally involve improving energy efficiency, saving water, indoor environmental quality and waste management, etc. They are often difficult and risky. However, the implementation of green technology requires additional processes, advanced materials, and mature expertise [14]. Implementing these green technologies, which are complex to design and difficult to build, means that projects cycle will be extended.

2.3.3 Late and backward development

The first evaluation system, BREEAM, was proposed in 1990[15]. Restricted by the economic development environment, the concept of green building did not enter China until the end of the 20th century. Then, the evaluation system gradually was improved after the promulgation of the Evaluation Standard (GB/T50375-2006) for Green Building [16]. Compared with the developed countries, both in design concepts and practical technologies, the research on green building has been developed late.

2.3.4 Lack of rating and certificating systems

China's green building evaluation standards have not been wildly accepted. Some builders would even choose BREEAM, LEED, and other evaluation standards from developed countries to prove their certification. Moreover, the present green evaluation lacks requirements for environment planning, construction management and operation, and the standards for building renovation rarely involve.

2.4 Opportunities

2.4.1 Great demand in the construction market

By 2010, China's construction market has surpassed the United States and has already passed the stage of overall high-speed development. With the steady growth in national economy as well as people's living standard, the scale of total investment in fixed assets continued to expand steadily. The regional strategic planning and urbanization process also develop rapidly, and the construction market demand is still strong.

2.4.2 Enhancement of environmental protection awareness

People usually complain about environmental pollution, especially when their life quality and physical health are threatened. Environment has become the main concern for the Chinese residents, especially urban residents, when choosing their living conditions and life style.

2.4.3 Government policy support

Chinese government has made great efforts in ecological civilization construction, environmental protection, and green development. China's 13th Five-Year Plan for the Development of Construction Industry in 2017 set the goal of scale of green buildings and application of green building materials. The government has been committed to building a resource-saving and environment-friendly society.

2.5 Threats

2.5.1 Low cost of traditional building

The market price of traditional materials is stable and predictable. Green building technology requires higher skills practitioners. Obtaining benefits from green buildings are a long-term process. For the builder, the early short-term benefits of the project are more attractive. Therefore, developers tend to choose traditional building projects.

2.5.2 Weak initiative of practitioners

Many developers prefer low prices materials and appliances. And construction technology process is simplified so as to shorten the construction period and investment payback period. The training and continuing resources for relevant practitioners are always lacking.

They lack initiative to learn green technologies and are not sensitive to new technologies.

2.5.3 Low acceptance for green building

More people accept the concept of green building, though few of them really understand green building technology. Price, transportation, and geography are the primary considerations, except green certification. In addition, the public also doubts the adverse effects of green technologies. For example, people are worried about the increase of insects in vertical greening and lighting and ventilation.

2.5.4 Insufficient government economic incentives

The government is regarded as an important stakeholder in promoting the development of green building. Government's key role is to stimulate demand for energy conservation and fiscal subsidies. However, the subsidy given by the state is not enough for the incremental cost per unit area of green public buildings in China.

3. STRATEGIC CHOICE OF CHINA'S GCB INDUSTRY

3.1 Network hierarchy structure based on ANP-SWOT model

ANP analysis process can be divided into four steps: establish the network hierarchy structure, paired compare and calculate the priority, construct the super matrix, and rank the alternatives.

A hierarchical structure was first established. And factors and alternative strategies are transformed into a form in which they can be calculate by the ANP method. The hierarchy structure is shown in Fig 1.

The first level of the ANP model is the target layer, where the "choosing the best strategy" is placed. The SWOT factors and the SWOT sub-factors are in the second and third levels respectively. The last level of the structure is a collection of alternative strategies.

3.2 Model calculation

3.2.1 Priority of SWOT sub-factors

Focusing on overall goal of development strategy, experts are invited to examine and compare the four SWOT factors with Saaty's 1 (equal importance)-9 (absolute importance) scale for pair-wise comparison.

Thus, the interdependent priorities of the SWOT factors and SWOT sub-factors are calculated, The priorities are shown in Table 2. The priorities of goal on each sub-factor can be expressed as ω_1.

Table 2
Impact of goal on each sub-factor.

SWOT factor	Priorities of factor	Sub-factor	Priorities	ω_1
S	0.1794	S1	0.1677	0.0301
		S2	0.4836	0.0867
		S3	0.3487	0.0626
W	0.2324	W1	0.2987	0.0694
		W2	0.1390	0.0323
		W3	0.1965	0.0457
		W4	0.3658	0.0850
O	0.1655	O1	0.1462	0.0242
		O2	0.3150	0.0521
		O3	0.5387	0.0891
T	0.4227	T1	0.1478	0.0625
		T2	0.0893	0.0378
		T3	0.3515	0.1486
		T4	0.4114	0.1739

3.2.2 Priorities of the alternative strategies

The importance degrees of the alternative strategies

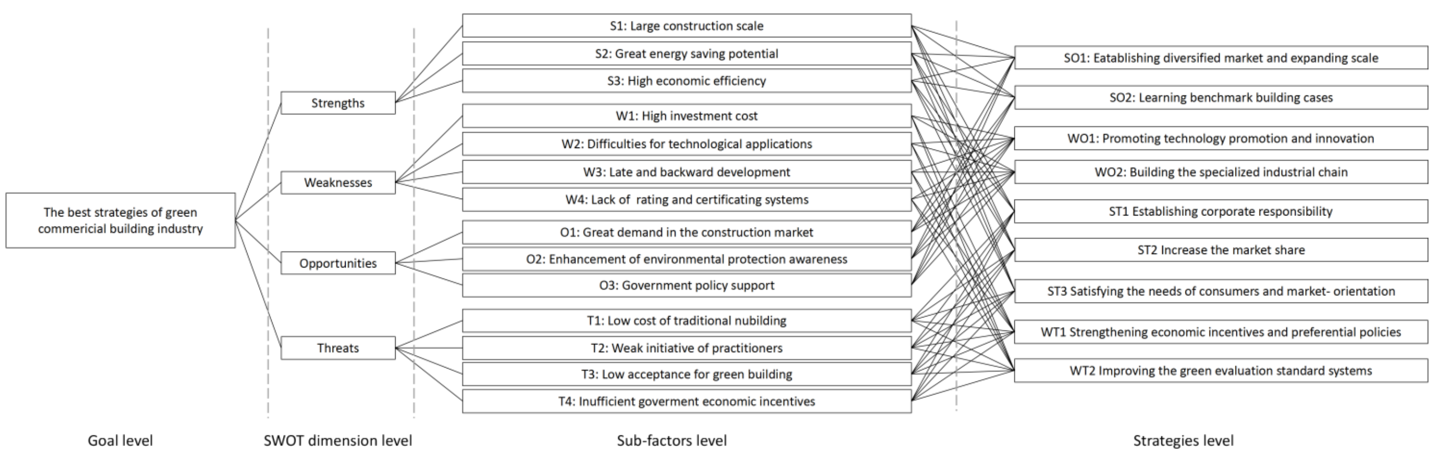

Fig 1 Network hierarchy structure of GCB development

with respect to each SWOT sub-factor are calculate through pairwise comparison. The super matrix ω_2, which represents the priorities of alternatives, is obtained based on normalized priority (Eq. (1)). Each column of matrix is represents the priority of the strategy based on each sub-factor. The weight vector is calculated by root method. For example, the impact of 9 strategies (i.e. large construction scale, great energy saving potential, high economic efficiency) on S1 can be presented in first column of the matrix with the relative weight of pairwise strategies comparison.

$$\omega_2 = \begin{bmatrix} 0.2156 & 0.0265 & 0.2191 & 0.0263 & 0.0346 & 0.0642 & 0.0520 & 0.0845 & 0.0679 & 0.0546 & 0.0237 & 0.0348 & 0.0366 & 0.0853 \\ 0.1803 & 0.0867 & 0.0501 & 0.1302 & 0.0974 & 0.0320 & 0.1591 & 0.0748 & 0.1161 & 0.1821 & 0.0387 & 0.1555 & 0.0380 & 0.0668 \\ 0.0688 & 0.1739 & 0.0889 & 0.1949 & 0.1544 & 0.1402 & 0.0535 & 0.1457 & 0.1312 & 0.1510 & 0.0625 & 0.0876 & 0.0596 & 0.0727 \\ 0.1173 & 0.0767 & 0.1004 & 0.0972 & 0.2207 & 0.1098 & 0.0683 & 0.1646 & 0.1661 & 0.1262 & 0.0558 & 0.0342 & 0.0713 & 0.0727 \\ 0.0392 & 0.2395 & 0.0407 & 0.0513 & 0.0363 & 0.0251 & 0.0282 & 0.0700 & 0.2003 & 0.0453 & 0.1615 & 0.1709 & 0.1709 & 0.0727 \\ 0.1211 & 0.0971 & 0.2476 & 0.0297 & 0.0353 & 0.0489 & 0.0816 & 0.2083 & 0.0910 & 0.0775 & 0.1662 & 0.0454 & 0.0619 & 0.0799 \\ 0.0949 & 0.0291 & 0.1591 & 0.0297 & 0.0222 & 0.0327 & 0.0381 & 0.1141 & 0.0910 & 0.0323 & 0.0860 & 0.0326 & 0.2420 & 0.0755 \\ 0.0851 & 0.1675 & 0.0427 & 0.3592 & 0.3036 & 0.2352 & 0.1782 & 0.0486 & 0.0558 & 0.2117 & 0.3301 & 0.3361 & 0.2200 & 0.3989 \\ 0.0777 & 0.1028 & 0.0515 & 0.0813 & 0.3119 & 0.3119 & 0.3409 & 0.0894 & 0.0895 & 0.1193 & 0.0754 & 0.1028 & 0.0999 & 0.0755 \end{bmatrix} \quad (1)$$

The ranking of alternative strategies can be expressed as ω_{alt}, which is the product of ω_1 and ω_2. The overall priorities of the GCB development strategies in China can be displayed as Eq. (2).

$$\omega_{\mathrm{alt}} = \omega_1 \times \omega_2 = \begin{bmatrix} 0.0663 \\ 0.0929 \\ 0.1047 \\ 0.0931 \\ 0.1035 \\ 0.0918 \\ 0.0889 \\ 0.2387 \\ 0.1200 \end{bmatrix} \quad (2)$$

Table 3 shows the alternative strategies evaluated by the ANP method.

Table 3
Ranking of alternative strategies

Alternatives strategies	**Priorities** ω_{alt}	**Ranking results**
SO1	0.0663	9
SO2	0.0929	6
WO1	0.1047	3
WO2	0.0931	5
ST1	0.1035	4
ST2	0.0918	7
ST3	0.0889	8
WT1	0.2387	1
WT2	0.1200	2

4. RESULTS AND DISCUSSIONS

According to the marking results from experts, the factors of SWOT analysis are compared and evaluated. Among these factors, the weaknesses and threats restrict the healthy development in industry. The most important factor is insufficient government economic incentives, which belongs to the external threats. Second, the relatively important factors are low acceptance for green building, government policy support, great energy saving potential, and lack of rating and certificating systems. The priorities and importance of the five factors are above 0.5834 in sum and account more than 50%. They are the key factors affecting the development of GCB in China.

4.1 Strengthening economic incentives and preferential policies

The promotion of green industry development needs governmental promotion and stimulation, especially when the investment is high. It is necessary for the government to introduce preferential policies and economic incentives. The incentive standards should be compatible with the evaluation level. Simplifying the process of auditing materials can make the certification process efficient. In addition, the target groups of economic incentives are not only developers, but also consumers and green products producers.

4.2 Improving the green evaluation standard system

The number of GCB certification is increasing and the evaluation criteria of green buildings need the identification of relevant departments and industry. The future evaluation system should meet requirements of emission reduction and pay attention to human experience. The requirement of green building should cover the whole life cycle of design, construction and operation.

4.3 Technology promotion and innovation

In order to satisfy the functional and economic needs of buildings, it is necessary to promote technological progress. First, in terms of technology development, more new materials and equipment should be encouraged. It is necessary to use clean energy to reduce pollution in buildings. Second, the direction of technological innovation should be gasped. Through training of industry practitioners，improve initiative to learn new technologies.

5. CONCLUSION

Green building is the inevitable trend in the development of the construction industry. In this paper, the ANP-SWOT model is employed to study the development of the GCB industry. And the development strategies are put forward according to the internal and external advantages and disadvantages. On the basis of hierarchy division, network analytic hierarchy process is introduced to evaluate the importance.

The results show that the main factors affecting the development of green building industry are insufficient government economic incentives, low acceptance for green building, and government policy support. Based on the factors, this paper puts forward nine development strategies and determines their priorities. It can be conclude that strengthening economic incentives and preferential policies, improving the green evaluation standard system, and promoting technology promotion and innovation are the most effective alternatives strategy.

ACKNOWLEDGEMENT

This work is supported by the Anhui Science and Technology Major Project under grant no. 17030901024.

REFERENCES

[1] Ziogou I, Michopoulos A, Voulgari V, Zachariadis T. Energy, environmental and economic assessment of electricity savings from the operation of green roofs in urban office buildings of a warm Mediterranean region. Journal of Cleaner Production, 2017; 168:346-56.

[2] Lim GH, Hirning MB, Keumala N, Ghafar, NA. Daylight performance and users' visual appraisal for green building offices in Malaysia. Energy and Buildings, 2017; 141:175-85.

[3] Wang J, Yu C, Pan W. Life cycle energy of high-rise office buildings in Hong Kong. Energy and Buildings, 2018; 167:152-64.

[4] Andrews KR. The concept of corporate strategy. Resources, firms, and strategies: A reader in the resource-based perspective, 1997. 52.

[5] Qiu G, Cui Y, Zhang X. Corporate strategy development based on SWOT analysis method. Science and Technology Management Research, 2015; 35(18):193-6.

[6] Saaty T L. Decision making-the analytic hierarchy and network processes (AHP/ANP). Journal of systems science and systems engineering, 2004;13(1):1-35.

[7] Kurttila M, Pesonen M, Kangas J, Kajanus M. Utilizing the analytic hierarchy process (AHP) in SWOT analysis—a hybrid method and its application to a forest-certification case. Forest policy and economics, 2000; 1(1):41-52.

[8] Saaty TL. A scaling method for priorities in hierarchical structures. Journal of mathematical psychology, 1977; 15(3):234-81.

[9] Jiang MP, Tovey K. Overcoming barriers to implementation of carbon reduction strategies in large commercial buildings in China. Building and Environment, 2010; 45(4): 856-64.

[10] Zhang L, Wu J, Liu H. Turning green into gold: A review on the economics of green buildings. Journal of Cleaner Production, 2018; 172:2234-45.

[11] Portnov BA, Trop T, Svechkina A, Akron S, Ghermandi A. Factors affecting homebuyers' willingness to pay green building price premium: Evidence from a nationwide survey in Israel. Building & Environment, 2018; 137.

[12] Chuen Chan, A.P., et al ., Critical Barriers to Green Building Technologies Adoption in Developing Countries: The Case of Ghana. Journal of Cleaner Production.

[13] Zhang X, Platten A, Shen L. Green property development practice in China: costs and barriers. Building and environment, 2011; 46(11):2153-60.

[14] Hwang B, Shan M, Supa'at NNB. Green commercial building projects in Singapore: Critical risk factors and mitigation measures. Sustainable cities and Society, 2017; 30:237-47.

[15] Ding ZK, Fan Z, Tam VWY, Bian Y, Li S, Illankoon IMC, Moon S. Green building evaluation system implementation. Building & Environment, 2018; 133:32–40.

[16] Zou Y. Certifying green buildings in China: LEED vs. 3-star. Journal of Cleaner Production, 2019; 208:880-8.