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Multiple Paths to Green Building Popularization Under the TOE Framework—A Qualitative Comparative Analysis of Fuzzy Sets Based on 26 Chinese Cities

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Abstract: Green buildings are a crucial element in achieving sustainable development. The use of green buildings can save energy and reduce greenhouse gas emissions. Promoting the widespread adoption of green buildings has become a significant concern in many countries or regions. Although previous studies have identified a range of key factors influencing the promotion of green buildings, further analysis of the combination of these critical factors needs to be conducted. Therefore, based on the technology–organization–environment (TOE) framework, this study utilizes the fuzzy-set qualitative comparative analysis (fsQCA) method to analyze survey data from 26 cities in China, resulting in four high-level configuration paths for the widespread adoption of green buildings. The results indicate that (1) achieving high levels of widespread adoption of green buildings does not depend on any single factor; instead, it relies on the collaborative interaction of multiple elements across technological, organizational, and environmental dimensions; (2) the potential substitution relationships between conditional variables among different configurations within the TOE framework indicate that science and technology expenditure and gross domestic product play more significant roles in the path combinations for the promotion of green buildings; (3) through the study of the substitutive relationships of four configuration paths, it was found that when a city faces challenges in the widespread adoption of green buildings, such as an insufficient number of green building technology patents or underdeveloped green finance incentive systems, it can still achieve efficient green building adoption by formulating corresponding policies and enhancing cultural value guidance for groups like developers, contractors, and consumers. Conversely, the same is true. This paper explores the combination of critical factors in green building adoption, providing insights into addressing the differing foundational conditions of cities in the process.

Keywords: green building; sustainability; fuzzy-set qualitative comparative analysis (fsQCA); technology–organization–environment (TOE)

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1. Introduction

In recent decades, energy consumption in buildings has continuously risen due to increased living standards and population growth. Green building was presented as a solution to multiple environmental, economic, and social problems. As one of the three primary industries, the construction industry consumes an enormous amount of energy, making its transformation an essential goal for achieving sustainable development [1,2]. The energy consumption of buildings accounts for about 40% of global energy use and 37% of global energy-related carbon dioxide emissions, making it a key area for global energy-saving and low-carbon development [3–6]. In China, in 2021, the energy consumption of residential buildings throughout their lifecycle accounted for 36.3% of the national energy consumption, and the total carbon emissions from residential buildings accounted for

38.2% of the national energy-related carbon emissions. Additionally, pollution and toxic gas emissions from construction activities are severe [7,8], causing many residents to suffer from respiratory diseases [9]. Green buildings reduce carbon emissions by 50%, 48%, and 5% in water usage, solid waste management, and transportation, respectively, compared to traditional buildings [10]. The popularization of green buildings can reduce the use of fossil fuels, improve energy efficiency, and lower carbon dioxide emissions throughout the entire lifecycle of building materials, equipment manufacturing, construction, and building use [11]. Green buildings can alleviate the energy crisis and mitigate the negative impacts of building activities [12]. Since the concept of green buildings was introduced, it has received a positive response internationally. However, due to the lack of a corresponding development path [13,14], China still faces many obstacles in the popularization process of green buildings [9,13], and the current state of green building adoption varies significantly between cities [15]. Given this background, to promote the development of green buildings in China, it is necessary to explore the promotion paths of green buildings in different cities, focusing on addressing the bottlenecks in green building implementation and providing the nation with actionable, replicable, and promotable development pathways.

The development of green buildings plays a crucial role in the global economy, simultaneously drawing the interest and attention of governments and scholars [16–18]. Countries like the United States, the United Kingdom, and Japan have established relatively mature frameworks for researching the development of green buildings [3,16]. Additionally, each state in the U.S. has formulated relevant green building policies based on its development circumstances to ensure the implementation of green buildings [19]. The UK Green Building Council has set minimum standards for carbon emissions in buildings to promote adopting green building practices [20]. However, developing countries still have no systematic standards for promoting green buildings. For instance, the government drives the implementation of green buildings in India. However, the northeastern states of India have yet to adopt the concept of green buildings and lack effective implementation plans to ensure widespread acceptance [21]. In Vietnam, green buildings have received significant attention but still face various risks that hinder their development [22]. Although green buildings have developed rapidly in China in recent years, the uneven foundation across different cities poses challenges to the widespread adoption of green building practices.

Previous research on popularizing green buildings has focused on the factors influencing their adoption. However, studies have been lacking on the relationships between these influencing factors. Past researchers have used methods such as the analytic hierarchy process (AHP), entropy weight method, and content analysis to study the factors affecting the promotion of green buildings, mainly involving technology [23,24], policy [23,25], and green finance [16]. In recent years, more and more scholars have noted that the factors influencing the promotion of green buildings are jointly determined by various factors such as the level of economic development, residents living standards, and mandatory laws and regulations [26]. Overall, although previous studies have identified a series of key factors influencing the promotion of green buildings, it has also recognized that these factors are interrelated. As demonstrated in ref. [27], there is still a lack of research on the specific combinations of factors influencing the promotion of green buildings.

This study focuses on identifying the main factors affecting the adoption of green buildings from three dimensions—technology, organization, and environment—based on the TOE framework. It primarily involves aspects such as green building technology patents (GBTP), level of digital technology (LDT), science and technology expenditure (STE), gross domestic product (GDP), government mandatory regulations (GMR), green finance incentive systems (GFIS), and guidance of cultural values (GCV). Furthermore, the study employs fuzzy-set qualitative comparative analysis (fsQCA) to empirically investigate the adoption of green buildings in 26 cities in China, analyzing the driving roles of different combinations of influencing factors. The main findings are as follows:

(1) It must be recognized that achieving widespread adoption of high-level green buildings does not depend on any single factor; instead, it relies on the synergistic cooper-

ation of multiple elements across technological, organizational, and environmental dimensions. Additionally, the potential substitutability of conditional variables between different configurations under the TOE framework suggests that science and technology expenditure and gross domestic product play a more significant role in the combination paths for urban green building adoption.

(2) We used fsQCA software to analyze the data and derived four pathways for promoting green buildings in China. Furthermore, we discussed the results in greater detail, concluding that the "technology-organization-environment balanced" pathway is the most suitable for promoting green buildings in China; the "organization-determined" pathway is the most efficient for the promotion of green buildings; the "technology-organization determined" pathway is the simplest for the promotion of green buildings in China; and the "technology-organization dominated" pathway is the most typical for promoting green buildings in China.

(3) When a city faces a lack of green building technology patents or an underdeveloped green finance incentive system in promoting green buildings, it can still achieve efficient green building promotion through the formulation of relevant policies and by raising public awareness about green building adoption, and vice versa. This work provides concrete theoretical insights and practical guidance for promoting green buildings.

The main content of this article is as follows: Section 2, based on previous research findings, proposes seven variable indicators affecting the adoption of green buildings under the TOE framework and introduces the study's breakthrough points and contributions. Section 3 presents the research methodology, case selection, and variable calibration. In Section 4, we use the fsQCA software to conduct necessity, sufficiency, and robustness analyses. Section 5 discusses the implications of different configuration results. Section 6 provides the conclusion.

2. Literature Review and Theoretical Framework

2.1. Research Related to the Popularization of Green Buildings

2.1.1. Study on the Influencing Factors of Green Building Popularization

As green building practices unfold in developing countries, the need to identify factors hindering and driving its spread rises [28]. Some studies have investigated the factors influencing the spread of green buildings. For example, Shi and Tam conducted structured interviews and surveys to study the factors hindering the adoption of green buildings in Shanghai and Hong Kong, finding that additional costs, technology, and information are the primary factors affecting the promotion of green buildings [24,29]. Liu et al. researched the progress of green buildings through a review of the literature using VOS viewer software 2009. They believe that factors such as the lack of government policies, imperfect technical capabilities, and unreasonable economic benefits have constrained the popularization of green buildings [23]. Wang et al. analyzed the current situation of green building promotion in China, employing the RBF–WINGS model to systematically examine the factors affecting the promotion of green buildings. They concluded that technological investment is a fundamental influencing factor in the development of green buildings. In contrast, industry scale and support from green finance are major influencing factors for green building development [16]. Anzagira and his team investigated relevant regulations that incentivize green building development in Ghana through a survey. They proposed that the path to popularizing green buildings should combine mandatory government regulations with government promotion and education [30]. Chen and others, following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, conducted a systematic review of the literature to study the critical factors for the successful adoption of green buildings, concluding that the roles of stakeholders and the government are crucial in promoting green buildings [31]. Hoffman pointed out that consumer purchasing intentions and awareness of green buildings are other significant factors influencing the adoption of green buildings [32]. In summary, research on the factors influencing green building adoption focuses on technology [5,24,29,33–36], mandatory government regulations [30,37–45], science and technology expenditure [16,46,47], green finance [48–54], and guidance of cultural values [30,55,56], indicating that the factors affecting green building adoption span multiple dimensions and are not determined by a single element.

2.1.2. Strategies and Methods for the Popularization of Green Building

Scholars have proposed strategies and methods for promoting green building based on the factors influencing its popularization. Hu and his team employed a mixed content analysis method to systematically review and analyze the policy and legal documents released regarding promoting green buildings in China from 2004 to 2021. They proposed strategies such as establishing information disclosure mechanisms, building a green finance system, and innovating policies to promote the popularization of green buildings [43]. Some scholars also suggested that joint actions among government, industry, and enterprises are necessary. This can be achieved by formulating robust policy systems and industry standards and providing financial and technical support to foster the development and popularization of green buildings [24,29]. Gan et al. pointed out that although regulations and policies help promote the popularization of green buildings, their effectiveness is closely related to their content and implementation [54]. Moreover, the government can enhance developers' and residents' awareness of green buildings through a series of promotional measures and increase support for green building technologies, which is a critical path to promote the development of green buildings [57]. Potbhare et al. developed a strategy for popularizing green buildings, emphasizing educational and guidance programs for developers, contractors, and relevant policymakers [58]. Wang and others proposed that the government needs to establish a green finance zone to support the development of green buildings and increase investment in green building technologies, among three strategies for promoting green buildings [16]. It can be seen that different scholars have offered various strategies to address the issue of promoting green buildings based on legal provisions, policies, and educational guidance.

2.1.3. Trend Research on the Popularization of Green Buildings

Research on the widespread adoption of green buildings needs to focus on the interrelationships between various factors. Ahmad conducted semi-structured interviews with 75 GB experts across six regions to explore the factors affecting green building adoption, emphasizing the connections between these influencing factors [27]. Agbajor et al. conducted a scoping review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines to investigate the key success factors for green building adoption in South Africa, highlighting the need for research to focus on government, GB product marketing, and management approaches, especially on the relationships between these elements, which future studies should prioritize [59]. Teng et al., using data from questionnaires and employing structural equation modeling (SEM), studied sustainable development strategies for green buildings. The results show that market development environments and ecological value have significant direct and combined effects on the sustainable development of green buildings. Economic value and social participation are key factors for the sustainable development of green buildings, and it is pointed out that future research needs to delve into the direct quantitative relationships between influencing factors [60]. The promotion of green buildings is a complex issue with systemic characteristics. In a system, the whole is composed of elements, and the promotion of green buildings cannot be understood by analyzing individual elements in isolation [61]. Only through the collaborative development of multiple factors can the promotion of green buildings be effectively advanced.

2.2. Popularization of Green Buildings and the TOE Framework

In this study, to ensure the scientific and comprehensive selection of factors influencing the adoption of green buildings, it is necessary to refer to existing research on these factors before determining them. Tornatzky and Fleischer first proposed the TOE framework (technology–organization–environment) and discussed the conditions for technology adoption from three levels: technology, organization, and environment [62]. The technological factors include characteristics of the technology itself, such as usability, relative advantage, complexity, and compatibility. The organizational level analyzes structural features that match the technology, such as scope, scale, and management structure characteristics. The environmental level focuses on factors like government regulations, market competitiveness, uncertainty, and cultural values.

2.2.1. Technology Level

Green building technology patents: Green building technology is indispensable for realizing the widespread popularization of green building [59]. For instance, Windapo and others further evaluated the sustainability of wood technology, mainly when used for housing [63]. To some extent, the green technology patents owned by cities can support the promotion of green buildings [64]. On one hand, compared to existing building technologies, green building technology can reduce carbon emissions throughout the building's entire lifecycle. To some extent, the increase in urban green building technology patents indicates that the city has a solid foundation for promoting green buildings. In the context of global resource depletion and environmental constraints, green building technology patents are considered vital to achieving sustainable construction [65]. On the other hand, green building technology is typically associated with environmentally friendly goals such as reducing carbon emissions and conserving resources [66]. Increasing green building technology patents in a city indicates the city's emphasis on the widespread adoption of green buildings. Therefore, by studying the green building technology patents of different cities, we can gain deeper insights into their attention to low-carbon technologies and assess their impact on promoting green building adoption.

Level of digital technology: The level of digital technology in different cities affects the development of green buildings [31,67], and the emergence of digital technology has significantly transformed the construction industry [59]. As China continues to advance and implement policies on digital economy and digital transformation, the level of digital technology in China will continue to improve. The maturity and application of digital technology will reconstruct the construction model of the industry [68,69], becoming a new engine for the widespread popularization of green buildings. Digital transformation involves improving the physical realm by integrating information, computing, communication, and connectivity technology [70]. In promoting green buildings, digital technology can address resource misallocation issues, enhance production efficiency [71], and overcome time and space limitations, facilitating information flow and improving coordination efficiency among construction enterprises [72]. Advanced digital technology plays a crucial role in the widespread popularization of green buildings.

2.2.2. Organizational Level

Science and technology expenditure: Compared to green building projects in other countries, China's green building projects are government-centric at the administrative level, so the government's financial strength, determined by economic conditions, plays a crucial role in project implementation [73]. In 2017, China's investment in construction industry technology amounted to CNY 380 million, a 221.7% increase over ten years. The scale of technological investment has played a significant supporting role in the development of green buildings [16]. The popularization of green buildings is influenced by technology and materials, requiring more financial support than traditional buildings [74]. Therefore, a city's financial expenditure on science and technology provides support for fundamental and applied research and the training of scientific talent, alleviating the burden of R&D funding [23] and promoting the popularization of green buildings to some extent. Wang et al. point out that technological investment factors can be seen as core influences on the development of green buildings [16]. Research funds can also be used to develop more efficient energy-saving materials, renewable energy technologies, and intelligent building systems, which facilitate the design and construction of green buildings. As a result, cities with higher research and development investment often achieve faster technological iterations in the construction industry, making the popularization of green buildings not only technically feasible but also economically more attractive.

Gross domestic product: Economic strength is the primary force driving the development of green buildings [16]. Due to the increased costs of technology and materials, green buildings demand a higher level of consumer purchasing power, linking the efficiency of green building adoption to GDP. Prum and Kobayashi argue that GDP influences the development of green buildings [75]. Zou et al. also suggest that gross domestic product (GDP) represents local economic conditions and is expected to be the main driving force behind green construction [76]. GDP is an appropriate conditional variable for studying the development of green buildings. A robust local economy can boost the demand and supply of green buildings.

2.2.3. Environmental Level

Government mandatory regulations: The development of green buildings requires guidance and support from relevant laws and regulations by government agencies [16]. Green building policies are considered the most fundamental and practical pathway towards promoting green building [43]. Government regulations are crucial in encouraging the adoption of GB and sustainable construction practices [77]. By establishing stringent green building policy guidelines and implementation standards [31], the government ensures that new and renovated buildings must meet energy-saving and emission-reduction standards, significantly contributing to green building adoption [59]. Government mandatory regulations can enhance green buildings' social recognition and market competitiveness, further promoting their development.

Green finance incentive systems: Cities with a high level of green finance development typically have more advanced financial systems to support the research and innovation of green building technologies. They can provide more incentives and subsidies for green buildings [31]. The popularization of green buildings requires more financial support than traditional buildings [59], and stable and sustainable green finance policies can guarantee the widespread adoption of green buildings [23]. Green finance's role is primarily to direct funds towards resource-saving technology development and ecological environmental protection industries, guiding companies to focus on green and environmentally friendly production through subsidies [78]. In 2017, China invested CNY 119.5 billion in green building through green finance [16]. Kennedy and others discussed the background of China's green finance, noting that infrastructure projects like green buildings will see increased capital investment during the green transition [79]. Ng and Zheng studied the positive impact of green finance on the macro economy, highlighting its importance as a component of green building development [80].

Guidance of cultural values: In China, the government's emphasis on green buildings significantly promotes their widespread adoption. By publicizing green buildings on official websites, the government can enhance public awareness and understanding, making citizens recognize the importance of green buildings in improving energy efficiency, reducing environmental impact, and increasing living comfort. The government should initiate campaigns to encourage developers and tenants to embrace green buildings, which can increase the value of properties [23]. Government promotion not only educates the public about the concept of green buildings but also motivates the adoption of green building technologies and methods within the construction industry. The government can promote adopting green building standards through demonstration projects and incentives while highlighting the long-term benefits of green buildings for increasing real estate value and reducing operational costs through public awareness campaigns, thus attracting more active participation from developers and builders. Additionally, government promotion can enhance consumer's environmental awareness, leading more home buyers and tenants to prioritize green buildings when choosing residences, further expanding market demand.

The TOE framework has proven effective in explaining the causes of complex social phenomena and identifying influencing factors [81]. Existing research indirectly supports the TOE framework's applicability in studying green building diffusion pathways [82]. When it comes to the widespread adoption of green buildings, analyzing from the perspectives of technology, organization, and environment is both practical and advantageous. Based on previous studies, this paper identifies seven influencing factors across three dimensions: technology (T), organization (O), and environment (E), and establishes a model of factors influencing the adoption of green buildings, as shown in Figure 1. This model provides the theoretical foundation for the subsequent analysis of the configurations of influencing factors in green building diffusion using the fsQCA method.

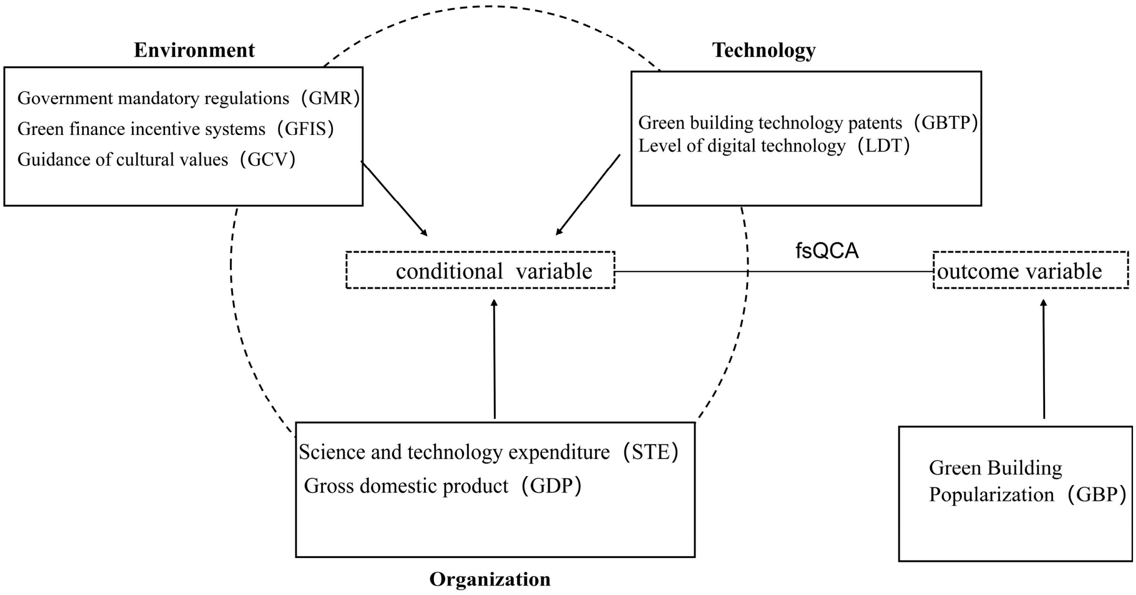

Figure 1. TOE theoretical model.

2.3. Research Breakthroughs and Contributions

First, the widespread adoption of green buildings is influenced by a combination of factors, not determined by a single one. Furthermore, previous research on the factors affecting the popularity of green buildings relied on the weight of indicators to determine their importance [46,83–85], which fails to reflect the complexity of the decision-making process behind the adoption of green buildings. Considering the influence of multidimensional conditions on the spread of green buildings, we based our study on the comprehensive TOE framework [33], using the fsQCA method to analyze the paths from three dimensions—technology, organization, and the environment—and drawing from previous studies on green building adoption, identified seven key influencing factors to explore the pathways for the promotion of green buildings.

Secondly, previous studies primarily employed reviews of the literature, hierarchical analysis, content analysis, questionnaire surveys, and structured interviews to explore strategies and approaches for promoting green building adoption. Some scholars emphasize that mandatory regulations on green building adoption established by the government can facilitate its spread [86–88]. Other researchers argue that fostering cultural values among stakeholders (developers, contractors, consumers) is critical to advancing green building adoption [58,89,90]. Additionally, some propose increasing fiscal expenditure and improving the green finance system to support green building adoption. The strategies and methods proposed in previous studies support green building adoption at various levels. However, due to differences in research focus and methodology, a comprehensive analysis encompassing the multiple factors influencing green building adoption has yet to be achieved.

Finally, through previous research findings, some scholars have recognized the importance of studying the relationships between the influencing factors of green building adoption in related research [27,59,60]. Additionally, the conclusions or limitations sections of various papers have highlighted the need for future research to focus on the relationships between these influencing factors for green building adoption, which, to some extent, proves that employing the fsQCA method to explore the pathways of green building adoption is an emerging research trend.

According to the above research, the factors influencing the widespread adoption of green buildings involve multiple aspects such as technology, policy, and green finance, all of which do not act independently. Additionally, due to the differing tools, methods, and research focus employed by various researchers, along with the numerous variables affecting the adoption of green buildings, these factors collectively contribute to the absence of a forced and efficient pathway for green building promotion. From a holistic perspective, more configurational research is still needed on the widespread adoption of green buildings, particularly regarding fsQCA analysis based on the TOE framework. The paths formed by the combined influence of multiple factors have yet to be fully validated. Exploring the dimensions and interrelationships of factors influencing decision-making can help understand the thought processes of decision-makers [91,92]. Therefore, this study aims to systematically analyze the causal relationships among various factors influencing the adoption of green buildings and, based on empirical research, summarize effective pathways for promoting green buildings.

3. Methods

3.1. fsQCA

Qualitative comparative analysis (fsQCA) is a theory-set analysis method oriented towards case studies, proposed by Ragin, which integrates quantitative and qualitative dimensions [91]. Ragin argues that the influence of causal condition variables on the outcome of social phenomena is not independent; most causal condition variables are interdependent. Therefore, to explain the underlying causes of social phenomena, a holistic, combinatorial approach is required [92]. Consequently, fsQCA focuses on configuration paths, specifically how different combinations of condition variables affect the outcome variable. Additionally, fsQCA posits that the combinations of condition variables leading to an expected outcome are asymmetrical, necessitating separate analyses of cases where the outcome occurs and where it does not to better explain differences between cases. The advantage of the fsQCA method lies in its combination of qualitative and quantitative research approaches. Traditional qualitative research typically can only analyze a small number of cases, limiting the generalizability of its conclusions. However, fsQCA can utilize scientific statistical methods to summarize results through comparative analysis of multiple cases, allowing research findings to be generalized. In addition, fsQCA differs from traditional quantitative research methods like the analytic hierarchy process and entropy methods. Traditional quantitative research assigns weights to individual variables to determine their importance, making it difficult to explain the complex causal relationships between multiple factors and outcomes. In comparison, fsQCA, through comparative analysis of multiple cases, explores the impact of different combinations of variables on outcomes and forms configuration paths of influencing factors, enabling better explanations of complex causal relationships. When using fsQCA for research, more than 10 cases are needed, with the optimal number of condition variables being 4 to 7 to identify the complex configurations of factors behind outcomes and establish appropriate explanatory models by conducting a comparative analysis of multiple case samples.

3.2. Case Selection

This paper focuses on the factors influencing the popularization of green buildings, with sample cases being representative and diverse. At the same time, it is necessary to select the case sample size based on the requirements of the fsQCA method. Therefore, based on the needs of the fsQCA method, standards for selecting case samples in this paper are established, mainly as follows: first, diversity. This study examines cases in China and aims to achieve the most significant possible heterogeneity among case samples with the minimum number of cases. The selected cities cover different regions, development levels, resource endowments, and work bases, meeting the fsQCA requirements of "maximum similarity" and "maximum heterogeneity", ensuring sample diversity [68]. Second, typicality. The selected cases have significantly influenced the province and even nationally, receiving widespread attention and recognition. Third, authority, taking into full consideration the accessibility of case sample data and the reliability of relevant information (as shown in Table 1).

Table 1. List of samples.

No.	City	No.	City
1	Xiamen	14	Qingdao
2	Hangzhou	15	Ningbo
3	Xining	16	Dalian
4	Yinchuan	17	Guangzhou
5	Shijiazhuang	18	Nanchang
6	Nanjing	19	Guiyang
7	Hefei	20	Lanzhou
8	Jinan	21	Fuzhou
9	Wuhan	22	Huhehaote
10	Shenyang	23	Nanning
11	Changsha	24	Taiyuan
12	Lasa	25	Haerbin
13	Chengdu	26	Haikou

3.3. Data Sources and Variables

3.3.1. Outcome Variables and Data Sources

This text is based on a model of factors influencing the promotion of green buildings according to configuration theory. To intuitively evaluate the level of green building promotion in different urban areas, this study uses the green building development competitiveness index as the outcome variable. The data sources are from the 2021 China Urban Green Building Development Competitiveness Index Report, jointly published by the China Urban Science Research Association and Tsinghua Tongheng Planning and Design Institute. The green building development competitiveness index objectively reflects the level of green building development in Chinese cities through multi-dimensional data analysis. This report is the first domestic research report focusing on cities and comprehensively assessing the competitiveness of green building development in Chinese cities.

3.3.2. Conditional Variables and Data Sources

The data on green building technology patents come from the China and International Patent Information Service Platform, the sole authoritative platform for patent applications and publications in China, built on the foundation of many advantages of foreign advanced patent search systems and decades of patent information service experience. The data on digital technology levels are sourced from the "Blue Book of Urban Digital Economy Index in China", which evaluates the digital technology levels of various cities. Data on scientific and technological expenditures come from the EPS database, using each city's science and technology spending as a benchmark. Regional gross domestic product (GDP) data are also sourced from the EPS database. Data on government mandatory regulations and policies are obtained from the PKULAW database. The green finance incentive system data are sourced from the statistical yearbooks of various cities, including national and provincial statistical yearbooks, environmental status bulletins, and some specialized statistical yearbook websites. The guidance data for cultural values are obtained from the official websites of city governments, where the term "green building" is searched. The search period is from 1 January 2021 to 31 December 2021, and the scope covers the entire text. Due to differences in search methods across websites, the standard during the search process is documents that contain the term "green building".

3.4. Calibrating Causal Conditions

Calibration is assigning membership degrees to sample cases within a set. Since the fsQCA method primarily analyzes the relationships between variable sets based on Boolean algebra, the original data must be calibrated for both conditions. Theoretical values in the data are uniformly handled by retaining two decimal places. According to relevant research, to convert raw data (ratio or interval scale values) into fuzzy membership scores, three qualitative breakpoints must be specified by setting three critical values: "full membership", "crossover point", and "full non-membership", also known as the three anchors. Generally, the membership point can be set at the 75th percentile or upper quartile, the crossover point at the median, and the non-membership point at the 25th percentile [61]. The calibration anchors for the variables in this study were calculated using Excel 2019. Then, the primary data for each variable were calibrated using the calibrate function in the fsQCA 3.0 analysis software. According to the calibration anchors set in Table 2, each variable was converted into a value between 0 and 1 representing set membership. The closer the calibrated value is to 1, the higher the degree of membership in the corresponding set. Conversely, the closer the value is to 0, the lower the degree to which the variable belongs to the corresponding set. The membership degree of the calibrated variable set ranges between 0 and 1. We adjusted the calibrated membership degree of 0.5 to 0.501, as a value of 0.5 makes it difficult to classify cases, and we wanted to prevent them from being excluded from the experiment. The results of the data calibration are shown in Table 2.

Table 2. Data calibration results.

Variable		Calibration			Description			
		Fully In	**Crossover**	**Fully Out**	**Mean**	**SD**	**Max**	**Mix**
Conditional variables	GBTP	266	153.5	47.25	172.30	148.96	519	3
	LDT	74.45	70.35	66.43	71.56	8.55	90.1	56.2
	STE	983,954.25	369,316	107,380	627,556.23	691,123.39	2,012,478	22,702
	GDP	139,197,500	71,415,000	48,135,000	94,238,846.15	68,046,354.39	282,320,000	7,420,000
	GMR	32.75	25	8.25	23.73	16.17	61	3
	GFIS	0.47	0.43	0.30	0.40	0.15	0.65	0.08
	GCV	357.25	92	42.75	370.34	587.37	2204	2
Outcome variables	GBP	51.55	46.72	39.245	46.20	10.47	67.43	25.68

4. Results

4.1. Analysis of Necessary Conditions

Based on the fundamental principles and logical steps of fsQCA, we first need to conduct a necessity analysis of the condition variables to determine whether they are necessary conditions for the outcome variable. The necessity analysis will yield two indicators: consistency and coverage. In the fsQCA 3.0 calculation, consistency explains whether the variable is necessary. In the results, if the consistency value of a condition variable is more significant than 0.9, it is considered a necessary condition for the outcome, indicating that this condition is a core condition [93]. Additionally, the coverage indicator is used to assess the extent to which the condition variable explains the outcome variable; the more significant the coverage value, the stronger the explanatory power of the condition variable. Table 3 shows that the consistency in the necessity analysis does not exceed 0.9, leading us to conclude that there are no necessary conditions in this study.

Table 3. Necessity analysis of single variable.

Conditions	High-Level of GBP	
	Consistency	Coverage
GBTP	0.745553	0.790812
~GBTP	0.375097	0.351195
LDT	0.838360	0.838360
~LDT	0.273009	0.270084
STE	0.773395	0.831947
~STE	0.338747	0.313305
GDP	0.832947	0.833591
~GDP	0.290797	0.287462
GMR	0.805104	0.786848
~GMR	0.327920	0.332028
GFIS	0.681516	0.622229
~GFIS	0.403558	0.440784
GCV	0.750193	0.782889
~GCV	0.329466	0.313005

4.2. Analysis of Sufficient Conditions

After analyzing the necessity of individual condition variables, we further explored the sufficiency of multiple condition variables using a truth table. A truth table is a configurational table showing all combinations of condition variables leading to high-level outcomes. This study used the fsQCA 3.0 software to execute the Truth Table Algorithm command. After calibrating the fuzzy sets, the data were inputted into the software. Following the recommendations of Wagemann et al. [93], we set the raw consistency threshold, PRI consistency threshold, and case frequency threshold to 0.8, 0.7, and 1, respectively. We obtained the truth table data for high-level green building diffusion factors, and by eliminating logical remainders, we constructed a simplified truth table, as shown in Table 4. In presenting the results of the configurational analysis, it is important to clarify some of the critical points in the results. Due to the complexity of causal relationships, there is more than one configuration of conditions that affects the outcomes, and there may be overlapping parts among the configurations that explain the outcomes. Therefore, coverage is further divided into raw, unique, and solution coverage. Raw coverage refers to the proportion of cases that each configuration covers, including the overlapping parts explained by multiple configurations; unique coverage refers to the extent to which a single configuration explains the outcome after excluding parts that are the same as other configurations; outcome coverage is the total coverage, indicating the proportion of cases covered by all configurations. A consistency value greater than 0.8 indicates an ideal result.

The truth table analysis results of fsQCA include three categories: complex solution, intermediate solution, and parsimonious solution. These three outcomes correspond to different configuration paths formed by combinations of conditional variables. This study uses the conditions derived from the intermediate solution as the basis for the sufficiency analysis. Compared to the parsimonious solution, the intermediate solution is based on easy counterfactual analysis, includes only simplified assumptions, and provides greater interpretability, holding more reliable theoretical and practical significance. Furthermore, core conditions refer to those that appear in parsimonious and intermediate solutions, while peripheral conditions only appear in the intermediate solution [91]. Core conditions significantly impact the outcome, indicating a robust causal relationship between the condition and the outcome; peripheral conditions contribute as auxiliary factors, indicating a weaker causal relationship between the condition and the outcome. At the same time, since no data were more significant than 0.9 in the necessity analysis, various conditional variables were not adjusted in the counterfactual analysis, and the condition was set as presence or absence.

Table 4. Solutions with coverage and consistency.

Variables	High-Level of GBP Performance			
	H1	H2	H3	H4
GBTP	●		●	●
LDT	•	•	⊗	•
STE	●	●	●	●
GDP	●	●	Ⓧ	●
GMR	•	•	Ⓧ	Ⓧ
GFIS		•	Ⓧ	•
GCV	•	•	Ⓧ	Ⓧ
Consistency	0.958	0.954	0.92	0.931
Raw coverage	0.514	0.446	0.071	0.073
Unique coverage	0.155	0.094	0.042	0.033
Overall consistency	0.929916			
Overall coverage	0.687548			

Note: ● = core conditions exist; Ⓧ = core conditions miss; • = edge conditions exist; ⊗ = edge conditions miss; blank = the presence of conditions is not important for the result.

We conducted an in-depth analysis of sufficient conditions using a truth table, displaying all possible logical combinations, thereby revealing the configuration paths under various scenarios [94]. As shown in Table 4, there are four configuration paths for high-level green building clusters. Table 4 shows that the overall solution consistency is 0.954, indicating that the causal combinations have a high degree of assurance for the outcome. Furthermore, the solution coverage is 0.687, meaning these four causal condition paths can explain 68.7% of the cases. Similarly, Table 4 shows that all identified configurations exhibit high consistency and coverage, so the model is considered informative [95]. In summary, under the TOE framework, there are four pathways for achieving high-level green building adoption based on the interaction of seven factors: green building technology patents, level of digital technology, science and technology expenditure, gross domestic product, government mandatory regulations, green finance incentive systems, and the guidance of cultural values, as shown in Table 4.

4.3. Configuration Path Analysis

In the results of the configuration paths, the closer the overall coverage value is to 1, the higher the degree to which the computed combination of condition variables explains the outcome variable. When the overall consistency value of the results is close to 1 and not less than 0.8, it indicates that the computed combination of condition variables has a stronger connection with the combination of condition variables presented in the case data, and this combination of condition variables can be used to explain the outcome variable [96]. According to Table 4, the fsQCA software outputs four configuration paths for high-level green building adoption, with an overall coverage of 0.68, covering 68% of the case samples. The overall consistency is 0.92, indicating that these four configuration paths (H1, H2, H3, H4) have a strong explanatory power for high-level green building adoption.

4.3.1. "Technology-Organization-Environment Balanced" Path

Configuration H1: GBTP*LDT*STE*GDP*GMR*GCV. Green building technology patents, science and technology expenditure, and gross domestic product are core conditions; the level of digital technology, government mandatory regulations, and guidance of cultural values are peripheral conditions, and green finance incentive systems are irrelevant. This combination can lead to a high level of green building adoption. Regardless of the extent of improvement in green finance incentive systems, having a higher number of green building technology patents, science and technology expenditures, and gross domestic product, combined with the level of digital technology, government mandatory regulations, and guidance of cultural values, can achieve a higher level of green building dissemination. The original coverage of configuration H1 is 0.514, which can explain approximately 51.4% of urban cases, covering the most comprehensive range, and is the most applicable path for promoting green buildings in China. The core conditions of the H1 configuration path mainly consist of technical and organizational condition variables, supplemented by environmental factors such as mandatory government regulations and guidance of cultural values. Therefore, we have named this path the "Technology-Organization-Environment Balanced" path. Configuration H1 demonstrates that the widespread adoption of green buildings requires cities to have a solid GDP foundation. Additionally, higher science and technology expenditures provide an economic basis for the increase in green building technology patents. The development of green building technology demands substantial financial investment in science and technology, so cities need to strengthen their investment in technological research and development during the process of green building adoption.

4.3.2. "Organizational Decision-Making" Path

Configuration H2: LDT*STE*GDP*GMR*GFIS*GCV, "Science and technology expenditure", and "Gross domestic product" serve as core conditions. In contrast, the level of digital technology, mandatory government regulations, green finance incentive systems, and guidance of cultural values are peripheral conditions. "Green building technology patents" are irrelevant conditions, but high-level green building adoption can still be achieved. Regardless of the number of green building technology patents, cities that maintain a high gross domestic product level are capable of providing scientific and technological expenditure for the popularization of green buildings and cooperating with government mandatory regulations, green finance incentive systems, and cultural values guidance can achieve a high level of green building adoption. The original coverage of the configuration H2 is 0.446, which can explain approximately 44.6% of urban cases. The core conditions of this path are entirely organizational, making it the most efficient path for the popularization of green buildings in China. Therefore, we name this path the "Organizational Decision-Making" path. Configuration H2 indicates that green finance incentive systems provide strong support for the development of green buildings. In promoting green buildings, due to the substantial upfront investments made by developers and the relatively low consumer acceptance of high-cost green buildings, cities need to improve green finance incentive systems to offer protection for producers and consumers. This is essential to encourage developers' enthusiasm and stimulate public demand for purchasing green buildings.

4.3.3. "Technology-Organization Determined" Path

Configuration H3: GBTP*~LDT*STE*~GDP*~GMR*~GFIS*~GCV. In the H3 configuration path, the core conditions are green building technology patents and science and technology expenditure, while the marginal condition of gross domestic product is missing. Even with the absence of core conditions such as the level of digital technology, gross domestic product, green finance incentive systems, government mandatory regulations, and guidance of cultural values, a high level of green building adoption can still be achieved. The H3 configuration path indicates that if a city has a high level of science and technology expenditure while promoting green buildings, it can provide financial support for the research and development of green building technology. From this, it can be seen that technological and financial support are crucial conditions for the widespread adoption of green buildings. The original coverage of the H3 configuration path is 0.071, which can explain about 7.1% of urban cases. This path is the most straightforward route for promoting green buildings in China. The core conditions of the H3 configuration path are mainly composed of technical and organizational level conditional variables; therefore, we name this path the "Technology-Organization Determinant" path. The H3 configuration indicates a close relationship between urban green building technology patents and science and technology expenditure. Technological advancements drive the promotion of green buildings. Thus, although the types and foundational conditions differ among cities, the government needs to ensure that science and technology expenditure is not only applied to the R&D of green building technology patents but also supports research development in other urban areas. The government promotes the diffusion of green buildings through technological progress.

4.3.4. "Technology-Organization Dominated" Path

Configuration H4: GBTP*LDT*STE*GDP*~GMR*GFIS*~GCV, core conditions include green building technology patents, science and technology expenditure, and gross domestic product. In contrast, peripheral conditions include the level of digital technology, green finance incentive systems, and the absence of mandatory government regulations and guidance of cultural values. Together, these can achieve a high level of green building adoption. This indicates that if a city can maintain a high GDP and invest significantly in science and technology expenditure, it can secure many green building technology patents. With the support of a well-developed green finance system and digital technology, even without government-imposed mandatory regulations or the promotion and education of green buildings, a high level of green building adoption can still be achieved. The original coverage of configuration H4 is 0.073, which explains about 7.3% of urban cases. It has the broadest coverage. Configuration H4 is the most typical path for the proliferation of green buildings in China, as its core conditions are mainly composed of technological and organizational variables. Additionally, supplementary green finance incentive systems at the environmental level are required. Therefore, we name this path the "Technology-Organization Dominated" path. H4 configuration paths indicate that in the absence of mandatory government regulations and guidance regarding cultural values, providing effective green finance incentive systems can also promote the adoption of green buildings. Therefore, we can understand that when a city lacks mandatory government regulations and the guidance of cultural values, establishing comprehensive green finance incentive systems through economic measures can serve as a substitute, thereby facilitating the spread of green buildings.

4.4. Robustness Test

The QCA method has three common approaches to robustness testing, including adjusting the qualitative anchors for calibration, changing case frequencies, and raising the consistency threshold [63]. Due to the limited qualitative research on adopting green buildings, this study lacks theoretical support for adjusting calibration anchors. Additionally, the sample size is 26, which is a medium sample size, and changing case frequencies could lead to configuration result deviations. Therefore, raising the consistency threshold was chosen for the robustness test. We adjusted the consistency threshold from 0.8 to 0.9 in sequence and found that the results remained unchanged, indicating that the configuration results are robust.

5. Discussion

5.1. Configuration-Specific Explanation and Case Analysis

The fsQCA software also provides corresponding cases during configurational path analysis. The cases for Configuration H1 include cities like Hangzhou, Nanjing, Wuhan, Guangzhou, and Hefei. For a detailed exploration, we will use Hangzhou as an example. Hangzhou is the core city of the Hangzhou metropolitan area. The State Council has confirmed it as the economic, cultural, and scientific education center of Zhejiang Province, as well as one of the central cities in the Yangtze River Delta. Consequently, its unique geographical location has contributed to the increase in Hangzhou's regional GDP, laying the foundation for promoting green buildings. In October 2020, the Ministry of Finance and the Ministry of Housing and Urban-Rural Development issued the "Basic Requirements for Government Procurement of Green Buildings and Green Building Materials (Trial)", and Hangzhou was selected as one of the first pilot cities for government procurement to support green building materials and improve building quality. Through mandatory government policies and regulations, Hangzhou's green building promotion has provided policy support, supplementing and incorporating green building materials that meet the criteria and focus on green energy-saving and low-carbon environmental performance. The Hangzhou municipal government has extensively solicited local green building material companies for their products, stimulating local businesses to enhance their support for developing green building technology patents and invest significantly in scientific research funds, promoting the spread of green building practices. At the same time, Hangzhou strictly implements basic requirements and standards for green building and green material government procurement throughout project approval, design, construction, and performance acceptance. To some extent, these measures also guide the values of stakeholders involved in the building production process.

Examples of H2 configuration cases include Nanjing, Qingdao, Fuzhou, and Guangzhou. We will conduct an in-depth exploration using Fuzhou as an example. As the capital city of Fujian Province, Fuzhou is the first city in China to receive the Global Sustainable Development City Award. It is one of the central cities in the Western Straits Economic Zone. Fuzhou's development of green buildings closely follows China's ecological civilization strategy. By the "Fujian Province Green Building Development Regulations (Draft) requirements", Fuzhou actively supports the development of green buildings.

Consequently, in formulating mandatory legal regulations, government promotion, and the long-term development of green buildings, the government has played a solid guiding role. Additionally, leveraging Fuzhou University and six other universities, Fuzhou has established a digital energy-saving monitoring platform, conducting energy consumption statistics on 4540 buildings to ensure steady improvement in the digital technology level of buildings. Research on H2 configurations indicates that the level of urban GDP significantly impacts the proliferation of green buildings, as GDP also determines the public's purchasing power for green buildings to some extent. Additionally, expenditures on science and technology ensure the development of a green finance system and digital technologies. Furthermore, the Fuzhou city government has mandated through compulsory laws and regulations that the development of the construction industry must be oriented towards green buildings. The government also interprets relevant regulations on green buildings through its website. It integrates the concept of green building development into daily administrative work, thus ensuring the efficient promotion of green buildings.

In the case of configuration H3, the example is Nanchang. To encourage the spread of green buildings, Nanchang has implemented the "Interim Measures for the Management of Special Energy Conservation Funds (Development and Reform Department)" to support the development of green buildings. This initiative has led construction companies to research green building technologies or use green materials in their projects to obtain subsidies or policy benefits from Nanchang, thereby somewhat increasing the number of patents. A typical example of configuration H4 is Changsha. Changsha has been awarded the title "Most Satisfactory City" for eleven consecutive years. This is because Changsha's development is mainly driven by the tertiary sector, with the city's finances relying heavily on tourism and local entertainment industries. Furthermore, the Changsha municipal government has implemented purchase restrictions on commercial housing, resulting in the lowest housing prices among provincial capital cities in China. Changsha also boasts over 60 universities, nurturing a large number of talents. With relatively low housing prices and high city satisfaction, Changsha attracts high-level talents to stay after graduation. Changsha has multiple innovation and entrepreneurship bases, providing a favorable environment for developing research institutions. In summary, the city of Changsha offers a favorable environment for the growth of high-level talent, which ensures the enhancement of the city's technological innovation capabilities. Finally, Changsha invests more in scientific and technological expenditures than other cities, developing numerous green building technologies. Additionally, in 2021, the Hunan provincial government introduced over 800 green investment and financing projects across 14 cities and states, with a financing demand of nearly CNY 250 billion. It also issued the "Green Investment and Financing Project Manual for Financial Support in Achieving Carbon Peak and Carbon Neutrality", providing green financial support for popularizing green buildings.

5.2. Analysis of Conditional Variable Substitution Relationships

The widespread adoption of green buildings results from a combination of factors [27]. First, by comparing the similarities and differences between configurations H1 and H2, we can further identify the potential trade-offs among technological, organizational, and environmental conditions. We found that when different cities have a good GDP and higher expenditure on scientific and technological development during the adoption of green buildings, the requirements for the level of digital technology, government mandatory regulations, and guidance of cultural values are relatively lower. Under these conditions, the green finance incentive systems (environment) and green building technology patents (technology) between the H1 and H2 paths can be substituted. Secondly, for configuration paths H1 and H4, it was found that cities with a strong GDP and significant scientific and technological expenditures also tend to have a higher number of green building technology patents. Furthermore, under the same level of digital technology, the guidance of cultural values (environment) and government mandatory regulations (environment) in configuration path H1 can substitute for the green finance incentive systems (environment) in configuration path H4. Finally, comparing the pathways for configurations H2 and H4 indicates that if a city has a strong GDP and substantial science and technology expenditure, the requirements for digital technology and green finance incentive systems are lower. In this case, a substitution relationship can be formed between green building technology patents (technology) and government mandatory regulations (environment), as well as the guidance of cultural values (environment).

The potential substitutive relationships among technological, organizational, and environmental conditions suggest that the conditions of science and technology expenditure and gross domestic product (GDP) play a more significant role in the widespread adoption of green buildings. The reason is that green buildings, as a new form of construction, involve increased costs in technology, materials, and maintenance throughout the building's entire lifecycle. Therefore, cities with high GDP levels or those capable of funding scientific and technological expenditures for green building research are more likely to achieve widespread adoption of green buildings. Additionally, research on the substitutive relationships in the H1, H2, and H4 configuration paths reveals that the three variables—environmental green finance incentive systems, two other environmental condition variables, and technological green building technology patents—can form substitutive relationships. In other words, given the exact configuration of other variables, these three can be interchanged under certain conditions. The substitution relationship among the three can, in some cases, compensate for the shortcomings of individual cities during the development process, thereby promoting the adoption of green buildings.

6. Conclusions

Exploring the interrelationships between the factors influencing the widespread adoption of green buildings can provide a better understanding of the pathways for green building promotion, offering theoretical support for developing green building promotion strategies in different cities. In this study, we conducted an empirical analysis based on the TOE framework theory and using the fsQCA method on seven key factors in 26 cities, including green building technology patents, level of digital technology, science and technology expenditure, gross domestic product, government mandatory regulations, green finance incentive systems, and cultural value guidance. The analysis resulted in four high-level pathways for the popularization of green buildings: H1 "Technology-Organization-Environment Balanced Type", H2 "Organization-Driven Type", H3 "Technology-Organization Driven Type", and H4 "Technology-Organization Dominated Type". Secondly, we analyzed the substitution relationships among conditional variables across different configurational paths. We believe that in the process of green building adoption if the core conditions of 'science and technology expenditure' and 'Gross Domestic Product' are the same across different configurational paths, the environmental dimension's 'green finance incentive systems' and the other two conditions from the environmental level (government mandatory regulations and guidance of cultural values), along with the technological dimension's 'green building technology patents,' can form substitution relationships. These substitution relationships among configurations make the path choices for green building adoption more flexible, compensating for the shortcomings in the development processes of different cities.

Moreover, STE and GDP are core conditions in the configuration paths that particularly need attention in promoting green buildings. Compared to traditional buildings, green buildings incur higher costs in various aspects, including the approval process during the initial stages of construction [97], the use of construction technologies and material selection in the mid-stage [98], as well as maintenance and usage in the later stages. Therefore, promoting green buildings places higher demands on urban GDP and STE, which forms the foundation for the proliferation of green buildings. Finally, it must be recognized that achieving a high level of green building proliferation does not depend on any single factor; instead, it relies on the collaborative synergy of multiple elements across technological, organizational, and environmental dimensions. The influence of each factor varies, and their interactions create different paths for the proliferation of green buildings. Research indicates that the choice of path for promoting green buildings impacts the efficiency of their proliferation.

The limitations of this study are as follows. First, all the data used in this study are from the same year, making it impossible to reveal the dynamics between the factors influencing the adoption of green buildings. The time effect in FsQCA is a crucial point for future research. Second, in the fs/QCA analysis, the generation of configuration paths is closely related to the number of research cases. Future research can explore more complex conditional variables by including more cases. Third, this study is based on the TOE framework used in reviewing previous studies. Due to the multitude of factors influencing the adoption of green buildings, we may have overlooked factors outside the TOE framework when selecting the conditional variables.

This research has practical significance for formulating government policies and can provide a reference for promoting green buildings in China. Each city can choose suitable strategies for promoting green buildings based on its circumstances rather than implementing homogeneous policies. Future scholars studying the promotion of green buildings can use these research conclusions to offer perspectives for empirical studies in specific cities.

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