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POLICIES OF IMPROVING DEVELOPERS' WILLINGNESS TO IMPLEMENT PREFABRICATED BUILDING: A CASE STUDY FROM CHINA

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Abstract. Multiple policies have been formulated to promote the development of prefabricated building (PB). However, ineffective policies increase the financial burden of the governments and hinder PB development. This study aims to identify effective policies and develop a practical policy framework to encourage developers to implement PB. Text analysis is to identify the policies related to PBs from the numerous samples. A survey is to verify the effective policies and explore their effects on the developers' willingness to implement PBs. The findings suggest that the current policy system of PBs is complete but uneven, focusing on environmental policies. The most cost-effective tools are land limitations, tax incentives, and financial support. Besides, policies are interrelated in affecting developers' willingness to implement PBs. It provides a reference for policy evaluation in application scenarios, which expands the literature research on the policy. Meanwhile, it provides a guide for policymakers to evaluate the effectiveness of policies and formulate practical policy frameworks to promote PB development.

Keywords: policy, prefabricated building, developers, text analysis, value analysis, policy framework.

Introduction

As the sustainability transitions, the prefabricated building (PB) has already become a hot topic in the construction industry and a principal response to carbon-neutral goals because of environmental enhancement, productivity improvement, and risk reduction (Arashpour et al., 2017; Hammad et al., 2019; Hong et al., 2018). The PB is mainly promoted by the government through policies rather than marketing (Wang et al., 2021a). However, the development of PB is not as expected because most developers are reluctant to adopt it in their projects, considering its high costs and risks (Gao & Tian, 2020). The policy as government intervention is formulated to urge developers to implement PBs in terms of mandatory regulations and incentives worldwide (Yeganeh et al., 2020; Zhang & Skitmore, 2012). More than 500 policies are formulated to develop the PB in over 29 countries/regions, i.e., the United States (US), Japan, Germany, the United Kingdom (UK), Canada, Singapore, Austria, etc. (Gao & Tian, 2020; Luo et al., 2021). For example, the British government issued a white paper to promote the development of industrial construction methods in 1945. The United Nations formulated guides for industrialization buildings in 1974. In Singapore, the Building and Construction Authority [BCA] prepared buildability guides for Prefabricated, Prefinished Volumetric Construction (PPVC) (BCA, 2000; Luo et al., 2021; Ministry of Housing and Urban-Rural Development [MOHURD], 2006). However, the developers are still unwilling to implement the PB, which hinders the development of PB and weakens the government's credibility. Hence, it is necessary for the government to identify the applicable policies that promote developers to implement PB.

The development of PB varies in different countries. For example, the proportion of prefabricated projects is 90%, 90%, and 80%, respectively, in the US, Japan, and Sweden, while only 20.5% in China in 2020 (Xianjichina, 2021), although China's government has formulated policies to promote PB development, such as land limitation,

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technical standards, and regulatory control. The reason is that several policies are effective for promoting the development of PB, such as land limitation and subsidies, but other policies are redundant with low performance, such as technical guidelines (Blismas & Wakefield, 2009; Mao et al., 2016). Evaluating the effectiveness of policies is crucial for the government to promote the development of PB. The effects of policies are explored that can promote PB development. For example, incentive policies promote PB development through taxation measures, direct or indirect subsidies, and preferential policies (Arif & Egbu, 2010). Liang et al. (2019) stated that the floor area ratio bonus affects the developer's decision-making on prefabricated construction. In contrast, mandatory policies such as green energy-saving standards and land auction restrictions impel stakeholders to implement prefabrication (Bossel, 2000; Wang et al., 2019). Global governments formulate supportive instruments, such as price compensations, tax relief, or rewards, to promote green developers or offer directive instruments like a land limitation to punish non-green developers (Luo et al., 2021). Although the previous studies have explored the effects of policies on PB development (Arif & Egbu, 2010; Luo et al., 2021), few studies focused on the practical efficiency of these policies on the developers' implementation of PB, who is the decision maker in determining the construction method of a new project to a large degree. Besides, the previous studies only listed the policies related to PB (Adekanye et al., 2020; Wang et al., 2020), but few explored their redundancy in the processing considering the efficiency. To fill the gap, this study aims to assess the effectiveness of policy formulated on the developers' implementation of PB and propose a practical framework to promote the developers' implementation of PB. It expands the literature reviews on the policy research and also provides a proactive policy framework for the government to stimulate the developer's willingness to implement PB.

This study first identifies the policies related to PB using text analysis to achieve the aims. Then, multicollinearity analysis is conducted to remove the redundant policies. Third, value analysis is used to evaluate policy effectiveness. After, one-way analyses of variance and correlation analysis are conducted to identify the effects of policies on the developers' implementation of PB. Finally, a policy framework is proposed as the outcome.

1. Literature review

1.1. Policies related to the prefabricated buildings

Governments' policies are viewed as management decisions for promoting PB development (Sewerin et al., 2020). The policy is a specific technical apparatus and institution formulated by governments to achieve common objectives through regulations and political relationships (Daugbjerg & Kay, 2019; Zhao et al., 2020). A practical policy can achieve common objectives and increase the government's credibility. According to its operational functions, Rothwell (1985) divided the policies into supply-side, environmental, and demand-side, three typed policies. Supply policy is a tool that increases the adequate supply of new technology by stimulating productivity. For example, the government increases investments in technology innovation and research & development (R&D) related to PBs to enlarge its supply (Bucher et al., 2020). Governments can reduce the land supply for the conventional construction methods to urge developers to promote the PB (Xue et al., 2021). Demand-side policy focuses on improving the overall social needs of the PB to expand their demands. For example, the governments provide loan preferences for the PB buyers or developers to increase the demands of the markets (Impullitti et al., 2020). The environmental policy emphasizes a healthy environment for new technology (Rothwell, 1985). Environmental policy utilizes the sector's regulations, planning procedures, and attitudes (Yemane & Eyob, 2020). For example, planning and blueprint are formulated to promote PB development and to achieve industrialization 4.0 (Wang et al., 2020). Besides, formal regulations and norms are made to encourage stakeholders to apply PBs in their projects in a formal environment.

Multiple policies have been formulated related to the PB as government interventive tools (Lee et al., 2020). Japan's government formulates incentive and mandatory policies to encourage PBs in terms of housing industry plans, preferential for low-income housing, regulations, standards, etc. (Luo et al., 2021). In the United States, the industry norms of quality and appearance were issued in 1976, and land preference and financial support are provided for PBs (Luo et al., 2021; Wang et al., 2020). The British government formulated several policies such as technical systems, standards, professional skill certification, and talent team training for the whole industry chains to promote PB development (Luo et al., 2021; Wang et al., 2020). In Singapore, laws, and regulations related to standardized specifications are formulated to impel stakeholders to implement PBs, while incentive policies such as cash rewards and personnel training enhance general contractors' reform and innovation (BCA, 2000; Luo et al., 2021). China's government also develops mandatory and incentive policies such as land limitation, cash subsidies, and tax relief to enhance stakeholders' implementation of PBs (MOHURD, 2017). Previous studies, such as Li et al. (2021) and Kong and He (2021), reviewed the policies related to PBs and classified them into the supply-side policy (i.e., talent training, technical support, innovation inputs, financial supports), environmental policy (i.e., technical standards, regulatory control, plans), and demand-side policy (government procurement, tax incentives, and price subsidies). However, few studies identified the effectiveness of these policies in quantitatively promoting PB development.

1.2. Effects of policies on the prefabricated building's development

The effects of policies on PB development are explored. Supportive policies such as financial subsidies and tax incentives promote PB development (Liang et al., 2019). Zhou et al. (2020) state that a strong government endorsement signal is sent to the companies when incentive policies are provided. Lee et al. (2020) suggest that demand-side policies can enlarge the demands of PBs by providing price subsidies or reducing product tax. Several policies are given to foster an environment for developing PB regarding reputational incentives, financial incentives, and penalties (Wang et al., 2021b). Prevailing financial vehicles are used to promote sustainable construction, such as bank loans, green bonds, tax incentives, etc. (Bossel, 2000; Jin et al., 2009). Based on the literature reviews, policies can promote the development of PB, but few studies identified the practical policies that affect the decision maker: developers' implementation of PB. Previous studies combed the relevant policies of PBs and explored their effects on the PB's development (Luo et al., 2021; Wang et al., 2020), but the current studies are far from reaching a final verdict on which policy instruments are most effective for enhancing developers' implementation of PB when they decide on the construction method of a project. Also, existing studies found that policies benefit PB development (Wang et al., 2020, 2021b), but few studies optimized the policy framework with the practical policies by removing the redundant policies. Hence, this study aims to identify the effective policies promoting developers' implementation of PBs and propose a policy framework by kicking out redundant policies.

2. Research methodology

2.1. Research design

Research methods involve text analysis and surveys. Text analysis is employed to identify policies that have been formulated related to PBs because it functions in text mining and information retrieval (Wang et al., 2019). It depicts the text quantitatively by identifying feature words from numerous samples. Semi-structured interviews are conducted to verify the measurements of policy obtained from text mining and explore the measurements of developers' willingness to implement PB. The questionnaire is to explore the practical policies that improve developers' willingness to implement PB through multiple quantitative analysis tools.

2.2. Measurements

The measurement items are identified to depict policy and developers' willingness to implement PB through text mining, literature review, and semi-structured interviews. First, text mining is used to identify the policies that governments have formulated to promote PB development. After that, based on the policy operational functions, these policies are divided into supply-side policy, demand-side policy, and Environmental policy. Finally, a total of 8 experts, who have rich experience in PBs and policy, are interviewed to verify (see Table 1). These experts are from the Ministry of Housing and Urban-Rural Development, Vanke, Longfor, and Broad Homes Industrial Group Co., Ltd., who have rich experience in PBs and related policies. As a leader in China's real estate industry, Vanke began to implement PB in 2003. Longfor, one of the top ten private real estate enterprises, has widely implemented prefabrication since 2018. The prefabrication is commonly implemented in Longfor's projects through developing the standard system, information management, and decoration integration. It is interesting to explore the transformation experience of PB. The Broad Homes Industrial Group Co., Ltd. is the first enterprise in China to provide global, large-scale, professional, and intelligent prefabrication manufacturing and services. According to the interview feedback, policy instruments are obtained: supply-side policy with four items, demand side policy with two items, and environmental side policy with five items.

The developer's willingness to implement PB is selected as the outcome variable in this study. Based on the literature review, semi-structured interviews for the 8 experts are conducted to verify the measurements of the developers' willingness to implement PB. According to the feedback, three measurement items are identified to measure developers' willingness to implement PB: enterprise strategies related to PBs, capital investment in PB, and the proportion of prefabricated projects in all construction projects (A. P. C. Chan & A. P. L. Chan, 2004; Goodier & Gibb, 2007; Wang et al., 2019). Table 2 shows the measurements used to design the questionnaire to conduct multiple analyses.

Table 1. Demographic characteristics of experts

Experts	Degree	Company	Position	Years of experience
Expert 1	Doctor	The Ministry of Housing and Urban-Rural Development	Research follow	10
Expert 2	Doctor	Vanke	Top manager	25
Expert 3	Doctor	Vanke	Top manager	20
Expert 4	Master	Vanke	Middle manager	12
Expert 5	Doctor	Longfor	Top manager	23
Expert 6	Master	Longfor	Top manager	17
Expert 7	Master	Broad Homes Industrial Group Co., Ltd.	Top manager	15
Expert 8	Master	Broad Homes Industrial Group Co., Ltd.	Middle manager	11

Table 2. Variables and the corresponding measurements

Variable	Measurement	Code	Reference
Supply-side policy (SP)	Raising skilled professional	SP1	Sewerin et al. (2020); Gao and Tian (2020); Luo et al. (2021); Xue et al. (2021)
	R&D of information technology	SP2	
	Land limitation	SP3	
	Technological innovation	SP4	
Demand-side policy (DP)	Public procurement	DP1	Lee et al. (2020); Xue et al. (2021)
	Trade supervision	DP2	
Environmental policy (EP)	Goal planning	EP1	Yemane and Eyob (2020); Wang et al. (2020); Luo et al. (2021); Xue et al. (2021)
	Financial support	EP2	
	Tax incentives	EP3	
	System policy	EP4	
	Regulations	EP5	
Developer's willingness to implement PB (DW)	Enterprise strategies for PBs	DW1	A. P. C. Chan and A. P. L. Chan (2004); Goodier and Gibb (2007); Wang et al. (2019); Xue et al. (2021)
	Capital inputs on PBs	DW2	
	The proportion of prefabricated projects in all construction projects	DW3	

2.3. Data collection

The data are collected from China because it provides an appropriate scenario where governments have formulated multiple policies to promote PB development, and the accounts of China's prefabricated projects are 42.75% of the global prefabricated projects in 2019 (MOHURD, 2021; Xianjichina, 2021). It provides a research scenario for this study to explore the practical policies improving the developer's willingness to implement the PB.

Four steps are conducted to collect the data: (1) Data collection. A rough search is driven from the official websites, i.e., the Ministry of Housing and Urban-Rural Development, the General Office of the State Council, the State Council of the People's Republic of China, and the State Commission of Development and Reform. The retrieval objectives focus on the laws, regulations, guidelines, or news related to off-site construction, PB, precast components, and industrialized building from 1952–2019. Data are also collected from the associations and news databases to replenish. (2) Data cleaning. Denoising is conducted by removing web links, missing content, useless words, and redundant data. Then, a policy database is derived, consisting of 23 policy documents. (3) Coding. Coding is conducted for the 23 policy documents in terms of "Document-Chapter-Item". (4) Database creation. A total of 146 policy instruments are obtained, including environmental policy, supply-side policy, and demand-side policy.

A questionnaire is designed to evaluate the effects of policies on the developers' willingness to implement PB. First, the 8 experts are interviewed to verify the policies identified by the text analysis (see Table 1). Then, a pilot survey is conducted to verify the questionnaire measurements based on the text analysis results and semi-structured interviews. Finally, data is collected online and onsite to explore the effects of policies on the developers' willingness to implement PB.

2.4. Analysis approaches

Quantitative analyses are conducted in this study consisting of multi-collinearity analysis, value analysis, one-way analysis of variance, and correlation analysis (see Figure 1). The multi-collinearity analysis is to remove the redundant policies and improve the structural consistency of the policy system. Value analysis is known as value methodology, value engineering, and value management. It is used to identify and develop value and innovation of technology and management strategy, which both government agencies and private industry have used to make decisions (Ghosh & John, 1999; Mostafaeipour et al., 2011). It reveals the relative quantity of input and output. Value analysis, as a practical tool, is not only a technical method to improve the value of projects and products but also a practical tool to evaluate management decisions and strategies (Ibusuki & Kaminski, 2007; Robati et al., 2021). The application scenarios of value analysis are expanded based on the value theory, referring to the conventional fields such as technical value, engineering value, and product value, and also emerging in new fields such as strategic management value and behavioral decision-making value. Considering that policy is a management strategy formulated by the government to achieve the expected goals, value analysis can be used to evaluate its values in this study. The items are optimal if the value is around 1.0 in the same project (K. Emami & T. Emami, 2020). In Eqn (1), the value is used to evaluate the performance of policy tools; the function means the utility of policy tools for the developer's willingness to implement PB; the cost means the efforts for obtaining the effectiveness of policy tools:

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}. \quad (1)$$

The one-way analysis of variance is to verify the effects of policies on developers' willingness to implement the PB.

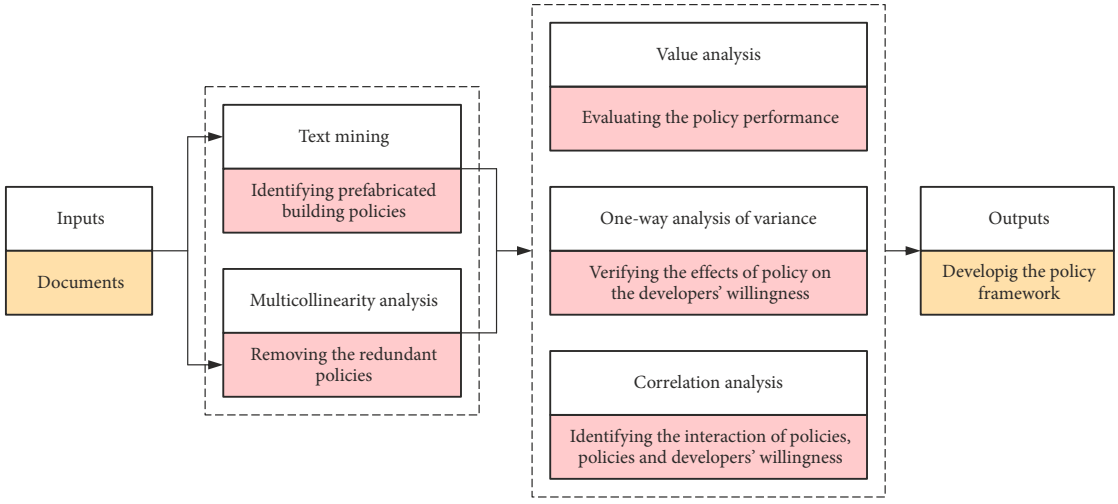

Figure 1. Research design

Correlation analysis is to identify the interaction relations between policy and developers' willingness to implement the PB.

2.5. Characteristics of the sample

A total of 146 policy tools are obtained from the 23 issues, including supply-side policy, demand-side policy, and environmental policy. Table 3 shows that 61.64% are environmental policies, 34.25% are supply-side policies, and 4.11% are demand-side policies.

After the pilot study, 250 survey packages are sent out, and 208 responses are obtained, with a response rate of 83.2%. The reactions are depicted in Table 4. Most respondents (53.4%) have rich experience in PB, and the respondents are mainly managers (69.2%), such as top managers, middle managers, and primary managers. Most of them (63.9%) are from private enterprises. Most of these respondents (67.8%) come from large companies with an over 5-billion-yuan sales scale. Respondents came from 26 provinces/municipalities directly under the central government, referring to Northeast China, North China, Central China, East China, South China, Southwest China, and Northwest China.

3. Results

3.1. Policy identification

Policies related to PBs are identified through text analysis (see Table 5). The results show that environmental policies are the crucial approaches with 61.64%, emphasizing the significance of a healthy environment for PB development. Supply-side policy instruments have a proportion of 34.25%. The finding suggests that governments offer supplies to developers and users to increase their requirements for PBs. For example, affordable housing projects are preferred to implement prefabrication by setting precast rates. Government intervention is a practical approach to remedy "market failure" through incentive policies (Liang et al., 2019). However, the proportion of demand-side policies is only 4.11%, revealing that demands for PBs are less than that of conventional on-site construction buildings.

For the environmental policy, system policy and regulations account for 26.71% and 21.92%, respectively, while goal planning, financial support, and tax incentives are paid less attention. The results suggest that government policies focus on many rules and standards to promote the development of prefabrication. The government contributes to establishing regulations and industry norms to promote the development of the PB, supplementing with fiscal support, tax, and financial policies.

Demand-side policies consist of public procurement and trade supervision. Public procurement is more significant than trade supervision with 4.11% because governments provide pilot cases to support the development of prefabrication. Meanwhile, integrated contractual modes are explored for PBs, such as engineering procurement construction, design–construction, integrated project delivery, etc. (Xue et al., 2010).

For supply-side policy instruments, R&D information technology and technological innovation are paid much attention in the proportion of 12.33% and 15.07%. It reveals that technology innovation and information shares should be emphasized to promote the development of prefabrication. Others, raising skilled personnel is still lacking for developers, and the knowledge of prefabrication needs to be strengthened.

3.2. Descriptive statistical analysis

All variables' reliability is tested using Cronbach's α. It means the variable items can meet the consistency if the Cronbach's α value is more significant than 0.7 (Xue et al., 2017). Cronbach's α of variables are shown in Table 6. The results suggest that all variables are consistent in this study, with more significant values than 0.70. Bartlett's test is conducted to verify the validity of these variables. The results show that the amount of KMO (Kaiser–Meyer–Olkin) is 0.906, and the Sig. (significance) is below 0.05 (see Table 7), revealing the goodness of these variables.

Table 3. Policy instruments related to PBs

Policy tools	Items	Detailed coding			
Supply-side policy	Raising skilled professional	6-2-10-1	6-2-10-2	9-4	12-14-4-5
		17-4-2-3	18-17-1	23-3-2	
	R&D of information technology	1-3-6-4	2-1-2	4-3-2-8	6-2-4-2
		6-2-5-1	6-3-11-4	6-3-12-2	6-3-13-2
		8-5-1	10-13-8	10-15	11-3-2
		12-14-4-4	17-4-2-4	18-17-2	22-1-5-2
		22-6-2	23-6		
	Land limitation	6-3-11-1	10-13-5	18-16-5	
	Technological innovation	1-3-5-3	1-3-6-2	3-3-3	4-3-2-6
		5-3-3	6-2-3-2	6-2-4-1	6-2-5-3
		6-2-5-4	8-5-2	10-7	10-9-1
		10-10-2	10-13-2	10-13-3	12-14-4-3
		17-4-2-2	22-2-4	22-3-3	22-4-2
		22-4-3	23-3-1		
Demand-side policy	Public procurement	4-3-2-4	6-3-11-3	10-13-7-1	16-11
		17-4-1-1			
	Trade supervision	10-13-7-2			
Environmental policy	Goal planning	1-2-3	4-2-3	6-1-1	6-1-2
		7-3-1-3	9-3	12-3-1	15-11-3
		17-4-1-2	18-2	22-2-2	23-2
	Financial support	10-13-6	18-16-4	22-6-3-2	
	Tax incentives	10-13-4	17-4-1-3	18-16-3	22-6-3-1
	System policy	4-2-1	4-3-2-1	4-3-2-3	4-3-2-7
		6-2-7-1	6-2-7-2	6-2-8	6-3-11-2
		6-3-14	6-3-15	7-3-1-1	10-1
		10-2	10-6	10-8	10-10-1
		10-12	12-3-2	12-12-7	12-14-4-1
		12-14-4-6	13-34-4	14-9	15-11-1
		16-9	16-10	16-23	18-16-1
		18-16-6	19-10	20-18	21-3-8-2
		21-4-2	22-1-5-1	22-1-7	22-3-4
		22-6-1	23-4-1	23-5	
	Regulations	1-3-6-3	2-3-2	3-4-3	4-3-2-2
		4-3-2-5	6-2-1	6-2-2	6-2-3-1
		6-2-5-2	6-2-6	6-2-9	6-3-12-1
		6-3-13-1	7-3-1-2	10-4	10-9-2
		10-11	10-13-1	12-14-4-2	12-14-4-7
		12-15-6	15-11-2	17-4-2-1	17-4-3
		18-16-2	21-3-8-1	22-3-1	22-3-2
		22-4-6	22-4-7	23-4-2	23-4-3

Based on variables' reliability and validity, descriptive statistical analysis is conducted to depict the characteristics of policy related to PBs (see Table 8). The means of policies are around 3.0, revealing the significance of existing policy instruments on the developers' willingness to implement PB. The standard deviations (S. D) values are about 1.0, showing that data is centralized in this study. The means of supply-side policies and environmental policies are more significant than demand-side policies, revealing that increasing market shares and fostering a healthy environment is necessary for developers to implement the PB. Raising skilled professionals, land limitation, and regulations are crucial for enhancing the developers' implementation of PB. Developers pay much attention to their enterprise strategies and capital inputs on PB.

Table 4. Demographic characteristics of the respondents

Characteristic	Frequency	Percentage (%)
Years of experience		
<3	97	46.6
3–5	52	25
6–10	34	16.3
11–15	16	7.7
16–20	6	3.9
>20	3	1.5
Position		
Top manager	28	13.5
Middle manager	69	33.2
Primary manager	47	22.6
Primary staff	64	30.8
Type of company		
Nationalized business	75	36.1
Private enterprise	133	63.9
Enterprise size		
<5 billion yuan	67	32.2
[5–10] billion yuan	92	44.2
>10 billion yuan	49	23.6
Geographical distribution		
Northeast China	46	22.10%
North China	40	19.20%
Central China	38	18.30%
East China	27	13.00%
South China	39	18.80%
Southwest	11	5.30%
Northwest	7	3.40%

Table 5. Details of PB policies

Variable	Measurements	Frequency	Percentage	Frequency	Percentage
Supply–side policy	Raising skilled professional	7	4.79%	50	34.25%
	R&D of information technology	18	12.33%		
	Land limitation	3	2.05%		
	Technological innovation	22	15.07%		
Demand–side policy	Public procurement	5	3.42%	6	4.11%
	Trade supervision	1	0.68%		
Environmental policy	Goal planning	12	8.22%	90	61.64%
	Financial support	3	2.05%		
	Tax incentives	4	2.74%		
	System policy	39	26.71%		
	Regulations	32	21.92%		

Table 6. Reliability of variables

Variables	Measurements	Cronbach's Alpha	
Supply-side policy	SP1	0.905	0.938
	SP2		
	SP3		
	SP4		
Demand-side policy	DP1	0.752	
	DP2		
Environmental policy	EP1	0.917	
	EP2		
	EP3		
	EP4		
	EP5		
Developer's willingness to implement PB	DW1	0.837	
	DW2		
	DW3		

Table 7. Results of the Bartlett's test

Item	Value
Kaiser–Meyer–Olkin	0.906
Approximate chi–square	3235.817
df	190
Sig.	0.000

Table 8. Descriptive of observed variables

Measurements	Minimum	Maximum	Mean	S. D
Raising skilled professional (SP1)	1	5	3.72	1.041
R&D of information technology (SP2)	1	5	3.54	1.071
Land limitation (SP3)	2	5	3.75	0.961
Technological innovation (SP4)	1	5	3.52	0.963
Public procurement (DP1)	1	5	3.22	0.826
Trade supervision (DP2)	1	5	3.18	0.880
Goal planning (EP1)	1	5	3.18	1.000
Financial support (EP2)	1	5	3.09	0.976
Tax incentives (EP3)	1	5	3.41	0.938
System policy (EP4)	1	5	3.65	0.937
Regulations (EP5)	2	5	3.82	0.951
Enterprise strategies of PBs (DW1)	1	5	3.26	1.019
Capital inputs of PBs (DW2)	1	5	3.20	1.000
Project proportion of PBs (DW3)	1	5	3.23	0.953

3.3. Value analysis

According to Table 9, the results show that land limitation and financial support have more excellent performance with the value of 1.25 and 1.03. The fact is that land limitation and financial support are the most effective policy tools to stimulate developers' willingness to implement PB considering their economic interests (Jiang et al., 2018). In contrast, system policy, regulation, R&D of information technology, and goal planning have less performance in many efforts and few unities. There is a lack of mature standard systems and technical specifications related to PBs being at the initial stage in China (Hong et al., 2018), leading governments to pay much input on system policy, regulation, and R&D of information technology. The value of trade supervision is 3.18. This finding suggests that governments should consider formulating trade supervision policies. According to the value analysis results, land limitation and financial support are the most effective instruments for enhancing developers' implementation of PB. In contrast, system policy, regulations, R&D of information technology, and goal planning have low effectiveness for promoting the developers to implement PBs with low values.

3.4. Multi-collinearity analysis

Variance inflation factor (VIF) is used to test the multi-collinearity between policies using SmartPLS 3.0 software (Surhone et al., 2004). It is no multi-collinearity between variables if the value of VIF is below 5.0 (García et al., 2015). The results state that there is no multi-collinearity between policy tools because the importance of VIF is from 2.0 to 3.0 in Table 10. It means the good structural consistency is for existing policy instruments with low redundancy. Namely, all the existing policies can be incorporated into the PB's policy system. According to the exploratory factor analysis, these policies are divided into supply-side, demand-side, and environmental policies.

3.5. One-way analysis of variance

One-way analysis of variance is conducted to identify the difference between dependent variables on the independent variable. Table 11 depicts the effect of enterprise attributes (i.e., sales, locations, and ownership) on the developer's willingness to implement PB. Enterprise sales significantly differ in the developer's willingness to implement PB. In contrast, project location and enterprise ownership have no difference at a 0.05 level. The findings reveal that the increase in enterprise scale affects developers' willingness to implement PB. When the enterprise scale reaches 20 billion, the change rate is not apparent (see Figure 2). Table 12 states the difference between supply-side policies and developers' willingness to implement PB. The results show that raising skilled professionals, R & D of information technology, land limitation, and technological innovation have significant differences in the developer's willingness to implement PB with the value of $P < 0.001$.

Table 9. Values of policies

Policy instruments	Mean	Frequency	Value
Raising the skilled professional	3.72	7	0.53
R&D of information technology	3.54	18	0.20
Land limitation	3.75	3	1.25
Technological innovation	3.52	22	0.16
Public procurement	3.22	5	0.64
Trade supervision	3.18	1	3.18
Goal planning	3.18	12	0.27
Financial support	3.09	3	1.03
Tax incentives	3.41	4	0.85
System policy	3.65	39	0.09
Regulations	3.82	32	0.12

Table 10. The results of multi-collinearity analysis

Variable	Measurement	VIF
Supply-side policy	Raising skilled professional	2.721
	R&D of information technology	2.689
	Land limitation	3.488
	Technological innovation	3.274
Demand-side policy	Public procurement	1.575
	Trade supervision	1.575
Environmental policy	Goal planning	2.872
	Financial support	2.761
	Tax incentives	2.599
	System policy	3.726
	Regulations	2.932
Developer's willingness to implement PB	Enterprise strategies of PBs	1.779
	Capital inputs of PBs	2.173
	Project proportion of PBs	2.074

Table 11. One-way analysis of variance of enterprise attributes

Measurement	Sum of Squares	F	P	Sig.
Enterprise sales	38.405	3.497	0.000	**
Project location	26.853	0.720	0.731	/
Enterprise ownership	23.160	1.123	0.344	/

Table 12. One-way analysis of variance of supply-side policy

Measurement	Sum of Squares	F	P	Sig.
SP1	45.732	4.163	0.000	***
SP2	56.214	5.036	0.000	***
SP3	29.284	3.116	0.000	***
SP4	43.105	4.708	0.000	***

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

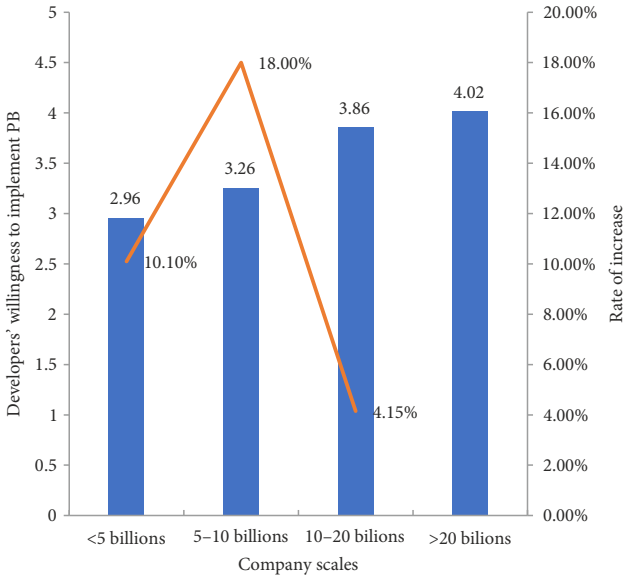

Figure 2. Company scales and developer's willingness to implement PB

Table 13. One-way analysis of variance of demand-side policy

Measurement	Sum of Squares	F	P	Sig.
DP1	18.237	2.407	0.006	**
DP2	16.387	1.849	0.043	*

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 14. One–way analysis of variance of environmental policy

Measurement	Sum of Squares	F	P	Sig.
EP1	61.661	6.891	0.000	***
EP2	66.500	8.264	0.000	***
EP3	53.177	6.694	0.000	***
EP4	70.216	10.223	0.000	***
EP5	54.926	7.749	0.000	***

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 13 suggests that public procurement and trade supervision have substantial differences in the developers' willingness to implement PB, but the diversity of trade supervision is low. Table 14 shows that the effects of environmental policy on the developer's willingness to implement PB are different with P < 0.001. The goal planning significance of the difference is the least while system policy significance is the most. Policymakers can promote PB development through unified standards and specifications.

3.6. Correlation analysis of policy instruments

Correlation analysis is to verify the closeness between variables using SPSS 21.0 software. Table 15 shows the proximity between supply-side policy instruments and the developers' willingness to implement PB. The results suggest that supply-side policies relate to the developers' willingness to implement PB entirely with p < 0.01. The R&D of information technology has a closer relationship with the developers' willingness to implement PB than other supply-side policies, with the value of the Pearson correlation being 0.421. The findings suggest that there are relations among supply-side policies. For example, technological innovation has a closer relationship with the R&D of information technology, while land limitation increases the requirement for skilled professionals. Demand-side policies correlate with the developers' willingness to implement PB, and there is an exact correlation between public procurement and trade supervision (see Table 16). However, trade supervision has fewer relations with the developers' willingness to implement PB. Further, environmental policies connect with the developers' willingness to implement PB (see Table 17). The results suggest that all the environmental policies have closer relations with the developers' willingness to implement PB than supply–side and demand–side policies with a higher Pearson correlation. The financial subsidies may promote the goal planning of PBs with the high correlations between EP1 and EP2. The effectiveness of system policy is related to financial support, tax incentives, and regulations.

Table 15. Correlation analysis of supply-side policy and the developers' willingness to implement PB

Variable	Index	SP1	SP2	SP3	SP4	DW
SP1	Pearson Correlation	1	0.641***	0.776***	0.636***	0.337***
	Sig. (2-tailed)	–	0.000	0.000	0.000	0.000
SP2	Pearson Correlation	0.641***	1	0.660***	0.767**	0.421***
	Sig. (2-tailed)	0.000	–	0.000	0.000	0.000
SP3	Pearson Correlation	0.776***	0.660***	1	0.750**	0.298***
	Sig. (2-tailed)	0.000	0.000	–	0.000	0.000
SP4	Pearson Correlation	0.636***	0.767***	0.750***	1	0.389***
	Sig. (2-tailed)	0.000	0.000	0.000	–	0.000
DW	Pearson Correlation	0.337***	0.421***	0.298***	0.389***	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	–

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 16. Correlation analysis of demand-side policy and the developers' willingness to implement PB

Variable	Index	DP1	DP2	DW
DP1	Pearson Correlation	1	0.604***	0.258***
	Sig. (2-tailed)	–	0.000	0.000
DP2	Pearson Correlation	0.604***	1	0.165*
	Sig. (2-tailed)	0.000	–	0.018
DW	Pearson Correlation	0.258***	0.165*	1
	Sig. (2-tailed)	0.000	0.018	–

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 17. Correlation analysis of environmental policy and the developers' willingness to implement PB

Variable	Index	EP1	EP2	EP3	EP4	EP5	DW
EP1	Pearson Correlation	1	0.770***	0.620***	0.658***	0.640***	0.503***
	Sig. (2-tailed)	–	0.000	0.000	0.000	0.000	0.000
EP2	Pearson Correlation	0.770***	1	0.634***	0.638***	0.601***	0.521***
	Sig. (2-tailed)	0.000	–	0.000	0.000	0.000	0.000
EP3	Pearson Correlation	0.620***	0.634***	1	0.754***	0.667***	0.493***
	Sig. (2-tailed)	0.000	0.000	–	0.000	0.000	0.000
EP4	Pearson Correlation	0.658***	0.638***	0.754**	1	0.793***	0.596***
	Sig. (2-tailed)	0.000	0.000	0.000	–	0.000	0.000
EP5	Pearson Correlation	0.640***	0.601***	0.667***	0.793***	1	0.544***
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	–	0.000
DW	Pearson Correlation	0.503***	0.521***	0.493***	0.596***	0.544***	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	–

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

4. Discussion

The policy system of PBs is complete, but it is uneven. Previous studies sorted out the policies related to PB development (Luo et al., 2021; Wang et al., 2020), but ignored the further exploration of the distribution of these policies. This study finds that the policy system of PBs consists of supply-side policy, demand-side policy, and environmental policy to stimulate developers to implement PB. However, there exists an uneven distribution of these policies. Governments pay more attention to environmental policies and ignore the demand-side policies. The reason is that the PB is mainly promoted by the government instead of the market, leading to demand-side or supply-side policies are inefficient for the development of PB in its early stage.

Land limitation, tax incentives, and financial support are the most cost-effective tools for promoting developers to implement PB. Previous studies explored the effects of policies on PB development (Li et al., 2018; Wang et al., 2021a), but ignored the comparison between the inputs and outputs of these policies. The value analysis suggests that land limitation, tax incentives, and financial support are the most cost-effective tools to promote developers' willingness to implement the PB, with their value around 1.0. Prior studies found that policies such as land limitation, tax incentives, financial support, and goal planning promote the development of PB (Adekanye et al., 2020), but the effectiveness of these policies is not explored. This study finds that land limitation, tax incentives, and financial support are the most cost-effective tools to promote developers' willingness to implement the PB because these policies affect developers' short-term benefits. While policies (e.g., system policy, regulations, technological innovation) are not cost-effective for the developers' willingness to implement the PB because these policies mainly affect developers' long-term benefits. The finding suggests that policymakers should formulate a policy system by matching developers' long-term and short-term requirements and providing a sustainable market environment for developers to implement PB.

Policies formulated have priority but are not redundant. Previous studies explored the policies related to PB development and verified their effects on promoting PBs (Luo et al., 2021; Xue et al., 2021), but few explored their priority. This study finds that all the 11 policies identified by the previous studies should be retained in the proposed policy framework because there is no multi-collinearity amongst them, according to the results of the multi-collinearity analysis. Meanwhile, priority should be considered when policymakers formulate policies. Based on the one-way analysis of variance, environmental policy and supply-side policy should be stressed in the primary stage,

while the demand-side policy can be increased with the development of PB. The reason is that the PB is mainly promoted by the government instead of the market in its infancy when a friendly environment should be provided through environmental policies instead of demand-side policies and supply-side policies. However, supply-side and demand-side policies should be increased with the development of PB. For example, several standards, technical specifications, and technological innovations should be formulated to optimize the prefabricated construction method when it achieves economies of scale. Hence, existing policies can be retained but implemented according to their priorities due to the development of PB.

Policies are interrelated and can affect developers' willingness to implement PB interactively. Previous studies explored the effects of policies on PB development (Blismas & Wakefield, 2009; Gao & Tian, 2020), but few focused on the relations between the policies. This study reveals that environmental policy, supply-side policy, and demand-side policy affect the developers' willingness to implement PB, and there are relations between these policies considering the Pearson correlations are significant at 0.001 level. The closeness between the policies is different. For example, the relations between system policy and regulations, with the correlation being 0.793, are closer than that of system policy and financial support, with the correlation being 0.638. It suggests that policies are interrelated, which may affect the developers' willingness to implement PB interactively.

A practical policy framework is proposed for improving the developer's willingness to implement PB according to their effectiveness and the development of PB. Previous studies reorganized the policies related to the PB (Kong & He, 2021; Li et al., 2018), but few optimized their policy framework from a dynamic perspective. This study proposes a practical policy framework discussed with the 8 experts based on the research results. The policy framework should be adjusted in different stages. In its initial stage, land limitation, financial support, regulations, raising skilled professionals, system policy, public procurement, and goal planning are required to improve developers' willingness to implement PB. In its expansion stage, supply-side policies should be enhanced to improve developers' willingness and increase the market shares, such as R&D of information technology, technological innovation, personnel training, and infrastructure investment. Environmental policies (i.e., tax incentives, system policy, regulations, goal planning) and demand-side policies (i.e., project management mode and public procurement) are still required. Demand-side policies (i.e., trade supervision and price controls) are necessary for expanding market demand at its sound development stage. Meanwhile, environmental policies (i.e., property rights protection, tax regulations, and industrial promotion) and supply-side policies (i.e., technological innovation, talent training, and infrastructure investment) are required to foster a sustainable market for the PB development (see Figure 3).

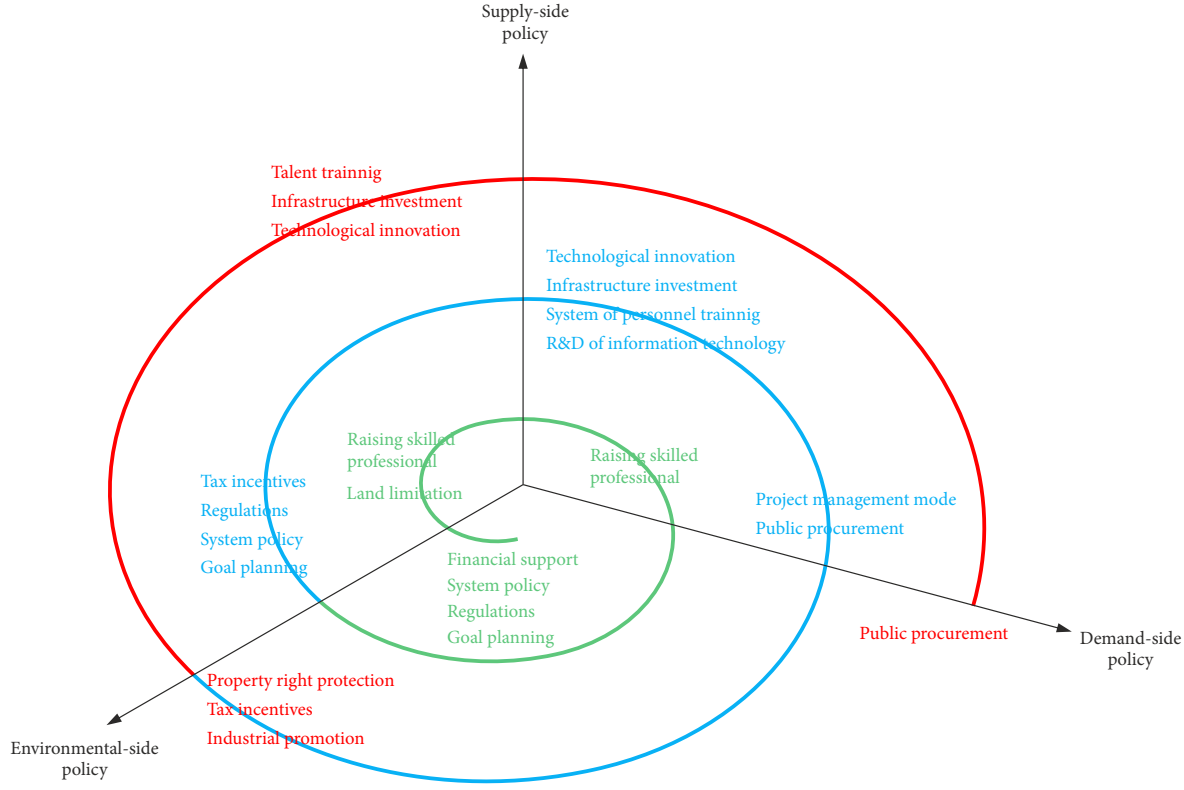

Figure 3. A dynamic policy framework

Conclusions

This study verified the effectiveness of existing policy instruments and their effects on the developers' willingness to implement PB to develop a proactive policy framework for promoting PB development. PB policies are classified into demand-side policy, supply-side policy, and environmental policy. Environmental policies obtained much attention with 61.64%, while the demand-side policies only make up 4.11%. For the developers, regulations and land limitations are the fundamental approaches compelling them to implement PB. In contrast, land limitation and financial support are the most effective instruments with practical value for the governments. Existing policies affect the developer's willingness to implement PB, and their effects vary with enterprise sizes. Besides, these policies interact with each other, but the closeness is different amongst policies. A dynamic policy framework is developed based on policy systematizes and PB development dynamicity.

This study makes two main theoretical contributions to the literature reviews on policy research and technology innovation. (1) Policy effectiveness can be evaluated by integrating multiple tools from the system perspective. Previous studies focus on the effect of policy on the objectives qualitatively, but ignore its value and redundancy systematically. This study combines multiple tools, such as value analysis, multi-collinearity analysis, one-way analysis of variance, and correlation analysis, to evaluate the value of each policy, explore the relations between the policies, and test the redundancy of the policy framework systematically. It provides a guide for policy evaluation in other application scenarios, i.e., carbon neutrality and building green retrofits. (2) It enriches the relevant research on technology innovation that relies on the government. Previous studies focus on the direct effects of technical values (i.e., perceived usefulness and perceived ease of use) and the indirect effects of external conditions on the users' usage behavior of new technology. This study focuses on the effect of external condition–policy on the user's usage behavior of new technology. However, several new technologies are promoted by the government, such as PB, green building, and carbon neutrality. This study verifies the direct effect of policy on the users' usage behaviour rather than the indirect effect through technical value. It expands a reference for exploring the path to promote technological innovation from the behavioral perspective.

The practical contributions of this study mainly lie in three aspects. (1) A practical framework is provided to identify the effectiveness of policy systems. Previous studies focus on the effect of policy, ignoring the value of the policy system (i.e., the relations between policies, the redundancy of policies, and cost performance). This study combines the analysis tools such as value analysis, multi-collinearity analysis, one-way analysis of variance, and correlation analysis to evaluate the effectiveness of the policy. It provides a practical tool for governments to identify effective policies. (2) Effective policies are identified to promote PB development. Previous studies have found the effects of policy on the PB's development, but the effective policies for the developers' willingness to implement PB are still unclear. This study explores the effectiveness of the policy on the developers' willingness to implement PB and finds that land limitation and financial support are the most cost-effective instruments for enhancing developers to implement PBs from the government's perspective. In contrast, developers pay more attention to these policies, i.e., raising skilled professionals, land limitations, and regulations. Hence, policymakers can formulate policies to promote PB development from a different perspective if necessary. For example, the government can formulate land limitations and formal regulations to urge developers to implement PBs when they want to reduce their fiscal expenditure on PB. In contrast, the government can also provide financial support for skilled professionals and developers to promote PB development with sufficient financial revenue. (3) A dynamic policy system is provided to promote PB development at different stages. Prior studies explored the policies that benefit PBs, but few evaluated the effectiveness of these policies considering the dynamics. Targeted policies should be formulated with the development of PB because the effect of policy may change. This study finds that environmental policy instruments can be enhanced in its initial stage; supply-side policy and environmental policy instruments can be integrated into its expansion stage, and demand-side policy and environmental policy instruments can be integrated into its sound development stage. The results provide a dynamic policy system for decision–makers to formulate practical policy based on the timeline.

One limitation of this study is that these policies are selected at the national level, although local governments formulate guidelines based on national ones. Further investigation will collect the data from the 34 provinces/cities to explore the policy environments for developing PBs. Besides, the relations between environmental, supply-side, and demand-side policy instruments are not discussed. Further analysis will identify these relations and design a network policy system for promoting PBs development.

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Author contributions

Yikun SU conducted the text analysis. Hong XUE prepared for the design of the manuscript and draft preparation, wrote and revised the manuscript. Shoujian ZHANG prepared for the design of the manuscript and draft preparation. Zhi SUN was responsible for data collection and analysis. Yirou SONG prepared for the original draft. Rui HAN revised the manuscript.

Disclosure statement

The authors would like to declare that they no competing financial, professional, or personal interests from other parties.

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