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Developing a suitability assessment model for Public Private Partnerships: a case in urban China

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Spatial heterogeneity is a fundamental aspect of Public Private Partnerships (PPPs). The appropriateness of PPPs applications varies across regions. While the assessment of suitability for PPPs is crucial, it has received limited scholarly attention. This study, using China as s representative case, developed a suitability assessment model and evaluated it across 287 prefecture-level cities in China. The results reveal considerable spatial variation in the suitability of PPPs within the country. Utilizing the natural breakpoint method, this study categorized Chinese cities into four distinct levels of PPP suitability: high, medium, low, and unsuitable. 219 cities were identified as either unsuitable or having low suitability for PPPs, suggesting that PPPs may not be broadly applicable in the current Chinese context. This study not only lays the groundwork for sustainable PPP application in China but also significantly contributes to shaping strategies for successful PPP implementation globally.

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Introduction

Public-Private Partnerships (PPPs), widely recognized as an innovative model for infrastructure and public service delivery, have attracted considerable attention and widespread adoption worldwide (Gifford et al. 2023; Song et al. 2022; Wang et al. 2023). The advantages of PPPs are diverse, including improved infrastructure construction, increased efficiency, and the shifting of risks from the public to the private sector (Klijn, 2009; Ke et al. 2024; Wang et al. 2022). However, the use of PPPs is not without controversy, particularly concerning questions of whether they provide real value for money and if their application has been excessive (Alcaraz Carrillo de Albornoz et al. 2023; Ma et al. 2023).

While PPPs are often viewed as a solution for urban development and economic growth, they are not a universal remedy (Ke et al. 2014). Some regions and sectors are less suited to PPP application, particularly those lacking stable cash flows (Wang et al. 2023). Excessive reliance on PPPs can lead to negative outcomes, such as increased local government debt and inefficiencies, particularly when public projects with no revenue potential are handed over to the private sector (Fuya et al. 2021). These potential risks have been evidenced in the recent expansion of PPPs in China (Cai et al. 2020) and in the development of models like PFI and PF2 in the UK, which highlight PPPs' significant limitations (Santandrea et al. 2016). Therefore, developing countries should apply PPPs cautiously, emphasizing thorough preliminary evaluations and oversight. This approach is crucial for effective PPP governance.

Spatial heterogeneity is a fundamental characteristic of PPPs (Cheng et al. 2024). The distribution of PPP projects varies spatially at both global and national levels. For example, the Private Participation in Infrastructure (PPI) Project Database shows that East Asia and Pacific, Latin America and the Caribbean account for 63.9% of global PPP investment. Countries with high volumes of PPP projects, such as the UK, India, and China, also exhibit regional disparities, with some areas having more projects than others (Cheng et al. 2020). The underlying reasons for these disparities are complex and have been explored from multidisciplinary perspectives. For instance, PPPs are influenced not only by urbanization and economic development but also by governance, regulatory environments, and actor networks (Ma et al. 2023). Variations in economic, social, demographic, cultural, institutional, and legal contexts significantly influence PPP development, necessitating nuanced applications to suit local environments (Cheng et al. 2024). Therefore, constructing a model to assess the suitability of PPPs in diverse regions, particularly in a vast and varied country like China, is both necessary and feasible.

The suitability of PPPs generally includes two dimensions. Firstly, the suitability of individual PPP projects, which pertains to whether a specific project is appropriate for the PPP model. This is typically addressed through project feasibility analysis and is subject to the government procurement framework's guidance on procurement method selection. Secondly, and more relevant to this study, is the suitability of the overall environment within a city for the adoption of PPPs. This study focuses on the latter dimension. The suitability of PPPs at the city level depends on several preconditions: PPPs are not universally suitable for all places, and their application is influenced by local factors such as social, economic, and fiscal conditions and government credit. Therefore, based on the geographies of PPPs, this study constructs a Suitability Assessment Model for PPPs, which is innovative both theoretically and practically.

The aim of this study is to explore the urban suitability of PPPs. Specifically, using China as a case study, it develops a PPP suitability assessment model to quantitatively evaluate the suitability of adopting PPPs in China's prefecture-level cities. The contributions of this study are multifold. First, it addresses a specific gap in existing studies by providing a detailed, place-based PPP suitability assessment, which has been lacking in current research. This assessment enriches the global understanding of PPP governance by integrating perspectives from various disciplines such as management, economy, finance, and law, and highlighting the spatial heterogeneity of PPP implementation. Second, it provides a scientific basis for the sustainable development of PPPs in China. Despite significant achievements since the new boom in 2014, PPPs in China face substantial challenges and require a transition towards sustainable practices. This study supports sustainable development by aligning with specific United Nations Sustainable Development Goals (SDGs), including SDGs 3, 6, 7, 9, 11, and 17. For example, PPP has accelerated the development of infrastructure and public services such as energy, health, and water to meet the needs of peoples, contributing to the achievement of Goal 3 good health and well-being, Goal 6 clean water and sanitation,and Goal 7 affordable and clean energy. Lastly, the insights from this study are valuable for other developing countries considering PPP adoption. While focused on China, the findings provide a relevant reference for other developing countries due to the global prevalence of PPPs and the widespread need for PPP suitability assessments.

The rest of the article is organized as follows. Section "Literature review" reviews the concept, governance, and performance of PPPs, and briefly introduces the development and characteristics of PPPs in China. Section "Methods and materials" describes the method and construction of the suitability assessment model for PPPs. Section "Results" presents the results. Section "Discussion" discusses the results in the context of theoretical frameworks, offering specific recommendations.

Literature review

PPPs are an elastic concept with a wide range including Build-Operate-Transfer (BOT), Private Finance Initiative (PFI), and Design-Build-Finance-Operate (DBFO) (Sun et al. 2023). Many countries and international organizations have different definitions. It is generally understood as a long-term partnership between the government and the private sector for the delivery of infrastructure and public services (Ke et al. 2024). The core principles of PPPs are risk sharing, benefit sharing, and long-term cooperation (Hueskes et al. 2017). The underlying assumption of PPPs is that cooperation between the public and private sectors can bring the improvement of efficiency and service in the infrastructure (Caloffi et al. 2017).

Since their global adoption, PPPs have often been scrutinized for their suitability across different projects. Not all infrastructure projects are appropriate for the PPP model, and numerous examples of failures underscore this misalignment(Wang et al. 2021). These failures highlight the critical need to assess the suitability of PPPs on a project-by-project basis, which is the first dimension of the suitability of PPPs explained in the Introduction section, i.e., the suitability of individual PPP projects. Despite the potential benefits of risk sharing and long-term cooperation, applying the PPP model to unsuitable projects can lead to inefficiencies, financial losses, and unmet public needs. Therefore, evaluating the appropriateness of PPPs for specific projects is essential to avoid these pitfalls and ensure successful outcomes. Studies such as those by Petersen et al. (2023), Xu (2023), and Vecchi et al. (2022) have explored this dimension extensively, though it is not within the scope of this paper.

The geography of PPPs is a neglected but important topic, as the suitability of PPPs often leads to significant spatial differences in PPP implementation and outcomes. PPPs are closely related to urbanization and territory factors, and are influenced by local conditions such as natural environment, social structure, economic development, and local culture (Almarri and Boussabaine 2017; Girth 2014; Hwang et al. 2013; Wibowo and Wilhelm Alfen 2014). These local factors can result in substantial variations in how PPPs are applied and their subsequent success or failure, even within the same country. This highlights the second dimension of PPP suitability mentioned in the Introduction section, i.e., the suitability of the overall environment within a city for PPP adoption, which is within the scope of this paper. Therefore, when developing policies to promote PPPs, governments must fully take into account these spatial differences of PPPs and avoid a one-size-fits-all approach. Instead, they should adopt targeted measures that account for the unique characteristics of different regions, ensuring that PPPs are tailored to local needs and conditions (Chou and Pramudawardhani 2015; Song et al. 2018).

Recent research on assessing the suitability of PPPs within a city for PPP adoption is very limited. Most past research has focused on evaluating the PPP environment as a whole or partially, such as by assessing legal frameworks, government PPP units, financial markets, and other macro factors influencing the adoption of PPPs(Cepparulo et al. 2023; Moore and Vining 2023; Garrido et al. 2017). Studies have often concentrated on broader, national-level analyses rather than city-specific evaluations. The perspective of putting the environment through the lens of PPP suitability is innovative and new. This approach emphasizes the importance of understanding local contexts in greater detail to ensure that PPP models are appropriately tailored to the specific needs and conditions of individual cities. By focusing on this aspect, our study aims to fill the gap in current research and provide a more nuanced understanding of PPP suitability at the city level.

China has experienced an extraordinary development of PPPs in China over the past decades (Cheng et al. 2023), making it an ideal site to demonstrate the model developed in this paper. China's rapid urbanization and economic growth have led to the widespread implementation of PPP projects, significantly contributing to the country's infrastructure development (Cheng et al. 2016). The availability of extensive data on PPP projects across diverse regions in China provides a robust basis for analysis. Furthermore, the varying regional contexts within China, from highly developed coastal cities to less developed inland areas (Zhang et al. 2015), offer a rich environment to test the applicability and effectiveness of the PPP suitability assessment model. Since the New Policy of PPPs in 2014, China has seen a surge in PPP projects, leading to a phenomenon known as "PPP fever" (Cai et al. 2020). However, the disorderly expansion of PPPs has caused serious problems, such as the local government debt crisis, project irregularities, and collusion between the government and enterprises (Ma et al. 2023). Recent government reviews and rectifications since 2022 have further enriched the data landscape, making China a comprehensive case study for examining PPP suitability. Therefore, leveraging China's extensive PPP experience and diverse data, this study aims to provide valuable insights that can be applied to other developing countries with similar aspirations for PPP development.

Despite significant advancements in PPP research from various disciplinary perspectives, a comprehensive understanding of the applicability and adaptation of PPP models to diverse regional contexts remains limited. Most existing studies have primarily focused on the experiences of Western countries such as the United Kingdom, France, and the United States. A critical challenge in global PPP development is effectively tailoring PPP models to local contexts. This is particularly evident in China, where rapid economic development has led to a proliferation of PPP projects. However, there is a notable gap in research addressing the specific suitability of PPPs within China's varied regional environments. This study aims to fill this gap by developing and demonstrating a state-specific suitability assessment model for PPPs based on extensive data from China's prefecture-level cities. By doing so, it enriches the global understanding of PPP governance and provides valuable insights that can be applied to other developing countries with similar aspirations for PPP development.

Methods and materials

The research design of this study is as follows (Fig. 1). First, the suitability assessment indicators system is constructed based on the research objectives and a broad literature review. Second, entropy weight method is used to assign weights to obtain the evaluation matrix. Lastly, TOPSIS method is applied to obtain the results of suitability.

Methods

Constructing the suitability assessment model for PPPs. In response to identifying factors influencing the decision to adopt PPPs, we designed a 'target-rule-indicator' framework for our PPP suitability assessment model, as illustrated in Table 1. At the target dimension, the model's objective is to evaluate a city's suitability for adopting PPPs, offering guidelines for PPP implementation tailored to local conditions. The rule dimension includes urban development needs, financial security, government credit, government regulatory capacity, local government efficiency, and urban development characteristics. Within the indicator dimension, we focus on several key metrics: Development needs are assessed using indicators of GDP, urbanization rate, and infrastructure investment; Local government efficiency is evaluated through the government-business relationship indicator; Fiscal capacity is gauged using financial revenue and financial self-sufficiency indicators; Government credit is measured by a government credit regulation indicator; Government regulatory capacity is determined based on the number of local PPP projects and local PPP demonstration projects; Urban development characteristics are appraised through environment sustainability and social sustainability.

The selection of rules and indicators for the PPP suitability assessment model was based on the principles, characteristics, and existing studies of PPPs. PPPs are a long-term cooperative relationship based on the contract between the public sector and private sector and aim to promote the delivery of infrastructure and public services in urban development. Therefore, local development needs of urban development and economic growth are the fundamental factors for adopting PPPs (Yang et al. 2013). For example, developed and highly urbanized cities with better infrastructure and less demand, and have a lower willingness to adopt the PPP. The government plays a leading role in PPP development, which is not only the leader in proactively launching the PPP policy, model, and projects, but also the key stakeholder in the PPP projects (Rohman, 2022). Therefore, local government efficiency, fiscal capacity, government credit, government regulatory capacity, and urban development characteristics are the critical factors for the success of PPPs, which are also the core criteria of the suitability assessment of PPPs. In terms of local government efficiency, the approval process and efficiency of government departments are important factors affecting the implementation of PPP (Hu et al. 2020). Existing studies demonstrated that local government efficiency significantly affects the cost of PPP contracts (Athias 2013; Hu et al. 2020). In PPP projects, local governments often bear the guarantee responsibility, and the fiscal capacity of a city determines the

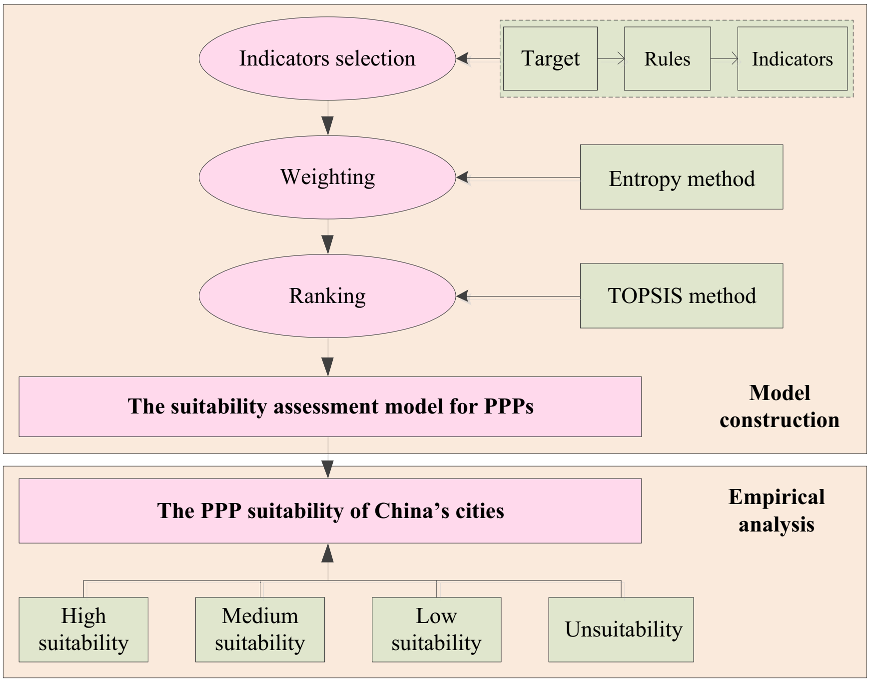

Fig. 1 Research framework.

Table 1 Suitability assessment model of PPPs.

Target	Rules	Indicators	Indicator description
Urban suitability of PPP	Development needs	GDP	Local GDP (Ten thousand yuan)
		Urbanization rate	urbanization rate (%)
		Infrastructure investment	Fixed asset investment/GDP
	Local government efficiency	Government-business relationship	The government-business relationship health indicator
	Fiscal capacity	Financial revenue	Local general public budget revenue/GDP
		Financial self-sufficiency	Local general public budget revenue/Local general public budget expenditure
	Government credit	Government credit	Local government credit regulatory ranking
	Government regulatory capacity	Local PPP projects	Number of local PPP in database of the MoF
		Local PPP demonstration projects	Number of the local PPP demonstration projects selected by MoF
	Urban development characteristics	Environment sustainability	urban air quality indicator
		Society sustainability	urban livelihood development indicator

attractiveness of local PPPs to private capital (Xu et al. 2014). Therefore, the financial capacity of the city will directly affect the suitability of PPPs. In addition, the government is not only the partner of the PPP project, but also the regulator, so the local government's regulatory ability and government credit of a city are the keys to protecting the legitimate rights of private sectors and public interests (Xu 2023). PPPs have a long construction period and huge risks. Therefore, the urban development characteristics, such as the amenity, attractiveness, vitality, and stage of development, are crucial to the success of PPP projects.

Processing framework. Assume the original matrix of PPP suitability assessment indicators as Eq. (1).

$$V = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} \tag{1}$$

Normalization method is used to process the raw data. The treatment of indicators with a positive effect (bigger is better) follows Eq. (2). The treatment of indicators with negative effects (smaller is better) follows Eq. (3). The normalized matrix (4) is obtained.

$$r_{ij} = \frac{v_{ij} - \min(v_{ij})}{\max(v_{ij}) - \min(v_{ij})} \tag{2}$$

$$r_{ij} = \frac{\max(v_{ij}) - v_{ij}}{\max(v_{ij}) - \min(v_{ij})} \tag{3}$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{4}$$

where, V is the original matrix; v_{ij} is the initial value of the i-th indicator in the j region; R is the standardized matrix; r_{ij} is the normalized value of the i-th indicator in the j region. $i = 1, 2, \ldots, m$, where m is the number of evaluation indicators. $j = 1, 2, \ldots, n$, where n is the evaluation area.

The entropy method is used to determine indicator weights. The calculation formula is as follows.

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{5}$$

$$H_i = -\frac{1}{\ln n} \sum_{j=1}^{n} f_{ij} \ln f_{ij} \tag{6}$$

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \tag{7}$$

The entropy weight W_i is used to weight the normalization matrix R to obtain the evaluation matrix Y. The calculation formula is as follows.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} = \begin{bmatrix} r_{11} \cdot w_1 & r_{12} \cdot w_1 & \cdot & r_{1n} \cdot w_1 \\ r_{21} \cdot w_2 & r_{22} \cdot w_2 & \cdots & r_{2n} \cdot w_2 \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} \cdot w_m & r_{m2} \cdot w_m & \cdots & r_{mn} \cdot w_m \end{bmatrix} \tag{8}$$

Let Y^+ be the positive ideal scheme of the i-th indicator in the evaluation data and Y^- be the negative ideal scheme of the i-th indicator in the evaluation data. The calculation formula is as follows.

$$Y^+ = \left\{ \max_{1 \le i \le m} y_{ij} | i = 1, 2, \cdots, m \right\} = \left\{ y_1^+, y_2^+, \cdots, y_m^+ \right\} \tag{9}$$

$$Y^- = \left\{ \min_{1 \le i \le m} y_{ij} | i = 1, 2, \cdots, m \right\} = \left\{ y_1^-, y_2^-, \cdots, y_m^- \right\} \tag{10}$$

Let D_j^+ be the distance of the i-th indicator from Y_i^+, and D_j^- be the distance of the i-th indicator from Y_i^-. The calculation formula is as follows.

$$D_j^+ = \sqrt{\sum_{i=1}^{m} \left(y_i^+ - y_{ij}\right)^2} \tag{11}$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} \left(y_i^- - y_{ij}\right)^2} \tag{12}$$

The T_j is the distance value, which refers to the suitability of the PPP in the j city. The larger the T_j, the more suitable the city is to adopt the PPP. According to the distance value ranking, the PPP suitability of China's cities is determined. The calculation equation is as follows.

$$T_j = \frac{D_j^-}{D_j^+ + D_j^-} \tag{13}$$

Entropy method. The entropy method is an objective empowerment method. Although it originated in physics, it has been widely used in many disciplines such as economics and management (Chen et al. 2024; Cheng et al. 2023). The entropy method determines the weight based on the variation degree of each evaluation indicator and the amount of information it reflects. In the assessment system, the entropy weight plays a role in characterizing the intensity of the indicator competition. The greater the dispersion of an indicator, the smaller the information entropy, and the greater the indicator weight. Therefore, entropy can be used to calculate the weight of each indicator, thereby providing a basis for the comprehensive evaluation of multiple indicators. In this study, the entropy method is used to weight the evaluation indicators. The general process is as follows. First, construct the judgment matrix of each evaluation indicator in each year. Second, normalize the judgment matrix to obtain a normalized judgment matrix. Third, determine the entropy of the evaluation indicator in each year according to the definition of entropy. Fourth, define the entropy of the *n-th* indicator to get the entropy weight. Finally, Calculate the weight value of the system.

TOPSIS method. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is used to address the evaluation and ranking of multiple indicators and multiple solutions encountered in the fields of social, economics, and engineering (Xiao et al. 2022; Zhang and Li 2020). According to the indicator properties and data of the alternative set, a set of optimal indicator data is regarded as the virtual positive ideal scheme, and a set of worst indicator data is regarded as the virtual negative ideal scheme. The distances of the scheme points from the positive ideal point and the negative ideal point are used to judge the evaluation scheme. This study combines TOPSIS and the entropy method. Based on the weights determined by the entropy method, TOPSIS is used for evaluation and ranking of the suitbility.

Data sources. We use data from 287 prefecture-level cities in China to demonstrate the model in this paper. The data for the assessment model is sourced from open databases. Indicators of GDP, urbanization rate, and infrastructure investment are obtained from the *China Urban Statistical Yearbook* released by the National Bureau of Statistics. Indicators of fiscal revenue and financial self-sufficiency are also derived from the *China Urban Statistical Yearbook* and are calculated using the equations shown in Table 1. Data on PPP projects and demonstration PPP projects are sourced from the PPP project database of the Ministry of Finance of China. Government credit data is obtained from the government credit index released by CreditChina (www.creditchina.gov.cn). Data for the government-business relationship indicator comes from the government-business relationship health index in the evaluation report of the government-business relationship in Chinese cities, released by the National Institute of Development and Strategy at Renmin University of China. The environment sustainability indicator is derived from the China Air Quality Index in *China's Ecological Environment Status Bulletin* issued by the Ministry of Ecology and Environment. The society sustainability indicator is sourced from the urban livelihood development index in the *China People's Livelihood Development Report* released by the School of Government Management at Beijing Normal University. Given the availability of data, this study uses cross-sectional data up to 2021.

Results

Based on the statistical data of 287 prefecture-level cities in China, the entropy model is used to determine the weights of the above 11 indicators (Table 2).

According to Eq. (13), the distance value T of each prefecture-level city to the ideal solution is calculated, as shown in Table 3. The larger the T value, the more suitable the city is to adopt the PPP.

In order to deeply study the suitability of PPPs and its spatial differences in China's cities, this study adopts the natural breakpoint method to categorize the 287 cities into four categories based on the assessment results, including high suitability (>0.3459), medium suitability (0.2229–0.3458), low suitability (0.1446–0.2228), and unsuitability (<0.1445) of PPP, as shown in Fig. 2.

Table 2 Weight of PPP suitability assessment indicators.

	Rules	Indicators	Weight	Data sources
Urban suitability of PPP	Development needs	GDP	0.23214	China Urban Statistical Yearbook
		Urbanization rate	0.02863	China Urban Statistical Yearbook
		Infrastructure investment	0.15049	China Urban Statistical Yearbook
	Fiscal capacity	Financial revenue	0.04605	China Urban Statistical Yearbook
		Financial self-sufficiency	0.06933	China Urban Statistical Yearbook
	Government credit	Government credit	0.01002	www.creditchina.gov.cn
	Government regulatory capacity	Local PPP projects	0.08760	Ministry of Finance of China
		Local PPP demonstration projects	0.18776	Ministry of Finance of China
	Local government efficiency	Government-business relationship	0.05063	report of the government-business relationship in Chinese cities
	Urban development characteristics	Environment sustainability	0.03013	China's Ecological Environment Status Bulletin
		Society sustainability	0.10721	China People's Livelihood Development Report

The PPP suitability of China's cities has significant spatial heterogeneity. The spatial characteristics of PPP suitability are as follows. First, provincial capitals and economically developed cities score higher and are most suitable for PPPs. Among the top 20 cities with high suitability, 14 are provincial capitals or sub-provincial cities, with a score above 0.3458. Second, cities in the eastern coastal region are more suitable for PPPs than cities in the central and western regions of China. Third, economic development is a major factor in determining the suitability of PPPs. In the weight of evaluation indicators, the local GDP and infrastructure investment accounted for 23.214% and 15.049% of the total 11 indicators respectively. Finally, most Chinese cities are currently not suitable for PPPs. The results show that more than 76% of cities still do not have sufficient conditions to adopt PPP in urban development. Among the 287 cities, the suitability score of 219 cities is below 0.2228, which indicates that PPPs are not suitable for large-scale applications in China.

A total of 18 cities with high suitability of PPPs, with scores ranging from 0.3459 to 0.6623, including Beijing, Shanghai, Shenzhen, Guangzhou, and Jining, etc. They are all national or regional central cities. These cities obtain most of the resources of the country or the province, have a developed economy and well-developed infrastructure, and have a high level of government credit, regulatory capacity, and government-business relations. The economic development of Heze, Jining, and Luoyang is in the middle and upper class of the country. However, these cities have rich experience and standardized practices in PPP applications. The number of PPP demonstration projects ranks first, second, and fifth in cities nationwide respectively. Local governments of these cities are able to implement PPP in a standardized, legal, fair, and just approach. In addition, these cities are in the process of rapid development and have a greater demand for infrastructure. Therefore, these cities are more attractive to private sectors and suitable for PPPs.

The second level is the cities with medium suitability of PPPs, which scores of 0.2229–0.3458, including 50 cities such as Zhengzhou, Xi'an, Yibin, Fuzhou, and Ningbo etc. 30% of these cities are provincial capitals or regional central cities. Some of these cities, such as Wuxi and Ningbo, are located in eastern China, with a developed economy, high fiscal revenue, and high urbanization level, although there is a certain gap with the first-tier cities of China. Other cities represented by Yibin, Chifeng, and Dongguan, although their economic development is not outstanding, rank high in the number of PPP demonstration projects, with an index weight of 0.18776 (ranking second among the 11 indicators), which proves that they have the experience and ability to successfully implement PPPs. Through the legal implementation of PPPs and strengthening of PPP project management, as well as the rapid urbanization of these cities, the efficiency of PPPs has been continuously improved in recent years, and attracted a large amount of private capital. For example, Yibin established the Municipal Finance Bureau PPP taskforce office and established the municipal PPP joint working group to implement PPPs. Until 2022, a total of 194 PPP projects in Yibin have been listed in the PPP database of the Ministry of Finance in China, with a total investment of more than 211.3 billion yuan. The number of PPP projects, the investment in PPP projects, the number of PPP projects in the implementation stage, and the number of projects under construction in Yibin all rank first in the Sichuan province. In addition, Chifeng PPP projects cover energy, municipal works, water infrastructure, transportation, and culture with the support of special funds from the central government, and greatly promote local urban development and economic growth.

The third level is the cities with low suitability of PPP, which scores of 0.1446–0.2228, covering 81 cities including Fuyang, Xuancheng, Shaoxing, Yangzhou, and Zibo etc. Except for the provincial capitals of Harbin, Taiyuan, Hohhot and Lanzhou, the rest are regular cities. Harbin and Taiyuan rank 31st and 57th in the GDP of all China's cities, and have a good economic foundation for PPP implementation. However, their government-business relationship indicator is only 31.92 and 34.65 respectively, and the urban development characteristics indicator is low, indicating that the local government does not provide adequate services to enterprises, the government transparency is low, and there is a certain obstacle to the private sector in PPP projects. Similarly, Hohhot and Lanzhou's economic development level, government-business relationship, government regulation and other indicators are not outstanding. The development of PPPs in these cities still needs to further improve the government functions, efficiency, service awareness, and regulatory capacity. The others are mainly inland cities. Although the economic development, urbanization, and infrastructure construction of these cities are all at the mid-to-upper level of Chinese cities, these cities have little PPP experience, with weak service awareness, low government credit, poor regulatory capacity, and low attractiveness to the private sector in PPPs.

The fourth level is the cities with unsuitability of PPP, with scores of 0.0001–0.1445, covering 138 cities including Weinan, Changzhi, Lhasa, and Zhangjiakou, which accounts for 48% of all cities in China. These cities are concentrated in the western and northeastern China. Compared with other cities, the cities with unsuitability of PPP have some common features. First, these cities generally have underdeveloped economies, low fiscal revenue, and even difficulty in self-sufficiency, low urbanization rate, and lagging infrastructure construction. Second, the governance capacity, regulatory capacity, and government credit of local

Table 3 Assessment results of PPP suitability in China's cities.

City	T	City	T	City	T	City	T	City	T	City	T
Beijing	0.6623	Urumqi	0.2532	Yan'an	0.1881	Tongling	0.1482	Lijiang	0.1247	Fangchenggang	0.0993
Shanghai	0.5271	Wenzhou	0.2511	Huaian	0.1878	Lu'an	0.1479	Shiyan	0.1240	Hegang	0.0988
Shenzhen	0.4518	Xuzhou	0.2472	Yinchuan	0.1873	Daqing	0.1475	Huainan	0.1237	Ya'an	0.0986
Guangzhou	0.4328	Hengshui	0.2467	Zhoukou	0.1856	Leshan	0.1471	Yangjiang	0.1233	Bayannaoer	0.0985
Jining	0.4282	Liaocheng	0.2451	Ningde	0.1840	Chuzhou	0.1462	Jingdezhen	0.1230	Yangquan	0.0982
Quanzhou	0.4274	Shijiazhuang	0.2444	Longyan	0.1832	Weinan	0.1445	Xinyu	0.1229	Jinzhou	0.0981
Wuhan	0.4154	Shenyang	0.2443	Baoshan	0.1809	Sanming	0.1443	yingtan	0.1228	Zhaotong	0.0970
Heze	0.4104	Nantong	0.2395	Taizhou	0.1808	Changzhi	0.1438	Datong	0.1226	Yunfu	0.0969
chongqing	0.4076	Zunyi	0.2383	Zhuhai	0.1803	Bengbu	0.1432	Xining	0.1221	Dazhou	0.0967
Suzhou	0.3954	Anqing	0.2356	Meishan	0.1798	Jingzhou	0.1420	Panzhihua	0.1219	Xianyang	0.0966
Kunming	0.3952	Yuxi	0.2350	Pu'er	0.1794	Liuzhou	0.1410	Ziyang	0.1216	Jiuquan	0.0964
Chengdu	0.3945	Hefei	0.2344	Zhumadian	0.1794	Lhasa	0.1405	Ezhou	0.1210	Guigang	0.0949
Tianjin	0.3853	Jingmen	0.2339	Yancheng	0.1780	Guangyuan	0.1403	Loudi	0.1206	Yichun	0.0948
Luoyang	0.3832	Tongchuan	0.2334	Huangshi	0.1766	Fuzhou	0.1382	Liaoyang	0.1204	Jinchang	0.0946
Qingdao	0.3821	Changzhou	0.2327	Dezhou	0.1760	Zhangjiakou	0.1378	Sanmenxia	0.1200	Shanwei	0.0946
Nanjing	0.3761	Bijie	0.2323	Nanping	0.1757	Wuzhou	0.1378	Meizhou	0.1194	Qitaihe	0.0945
Nanyang	0.3676	Baoding	0.2321	Zhenjiang	0.1756	Hulunbuir	0.1369	Wuzhong	0.1194	Jieyang	0.0942
Hangzhou	0.3674	Xiamen	0.2315	Tongliao	0.1755	Lianyungang	0.1364	Maozhou	0.1192	Hanzhong	0.0931
Zhengzhou	0.3458	Jiaxing	0.2309	Xinyang	0.1749	Huangshan	0.1358	Guilin	0.1181	Baise	0.0917
Xi'an	0.3438	Huizhou	0.2288	Bazhong	0.1741	Shangrao	0.1352	Nanchong	0.1180	Zigong	0.0909
Yibin	0.3438	Fuyang	0.2228	Hengyang	0.1725	Linfen	0.1349	Baiying	0.1178	Baoji	0.0898
Fuzhou	0.3380	Xuancheng	0.2220	Suqian	0.1703	Zhoushan	0.1349	Jincheng	0.1175	Baicheng	0.0895
Ningbo	0.3360	Shaoxing	0.2210	Yichun	0.1702	Xinzhou	0.1349	Luohe	0.1174	Suizhou	0.0889
Changsha	0.3326	Yangzhou	0.2165	Luliang	0.1699	Anyang	0.1348	Guang'an	0.1173	Jiamusi	0.0884
Chifeng	0.3185	Zibo	0.2143	Panjin	0.1691	Anshan	0.1343	Yongzhou	0.1170	Qinzhou	0.0879
Dongguan	0.3158	Xianning	0.2126	Wuhu	0.1677	Shaoyang	0.1341	Pingliang	0.1164	Fuxin	0.0871
Xiangyang	0.3153	Dongying	0.2123	Sanya	0.1677	yingkou	0.1338	Zhanjiang	0.1146	Chaozhou	0.0867
Ganzhou	0.3137	Liupanshui	0.2109	Putian	0.1665	huanggang	0.1337	Yiyang	0.1137	Qiqihar	0.0859
Taizhou	0.3107	Handan	0.2082	Xiangtan	0.1660	Zhuzhou	0.1331	Suzhou	0.1135	Ulanqab	0.0857
Wuxi	0.3105	Jinhua	0.2054	Hohhot	0.1660	Qinhuangdao	0.1331	Yulin	0.1133	Zhangjiajie	0.0852
Nanning	0.3030	Baotou	0.2041	Shangqiu	0.1658	Jiujiang	0.1331	Shuozhou	0.1123	Shizuishan	0.0839
Guiyang	0.3023	Harbin	0.2038	Jinzhong	0.1658	Huaibei	0.1328	Huaihua	0.1115	Jixi	0.0839
Tangshan	0.2995	Taiyuan	0.2029	Shantou	0.1650	Luzhou	0.1326	Shaoguan	0.1107	Hezhou	0.0828
Jiangmen	0.2993	sunshine	0.1998	Wuhai	0.1643	Jiayuguan	0.1314	Heihe	0.1103	Hechi	0.0819
Zhangzhou	0.2884	Jilin	0.1995	Jiaozuo	0.1630	Tonghua	0.1308	Fushun	0.1094	Shuangya Mountain	0.0813
Pingdingshan	0.2858	Chengde	0.1990	Puyang	0.1627	Chongzuo	0.1308	Longnan	0.1093	Dingxi	0.0806
Foshan	0.2786	Chizhou	0.1989	Ma'an Shan	0.1606	Neijiang	0.1304	Dandong	0.1086	Qingyang	0.0803
Cangzhou	0.2755	Zhongshan	0.1983	Quzhou	0.1592	Shangluo	0.1303	Qingyuan	0.1081	Zhangye	0.0799
Yeosu	0.2726	Ordos	0.1978	Binzhou	0.1577	Qujing	0.1294	Tongren	0.1071	Guyuan	0.0798
Yichang	0.2714	Siping	0.1944	Chenzhou	0.1574	Zhaoqing	0.1287	Hebi	0.1066	Tieling	0.0780
Weifang	0.2709	Changde	0.1944	Langfang	0.1554	Zaozhuang	0.1279	Beihai	0.1063	Tianshui	0.0753
Kaifeng	0.2708	Yueyang	0.1933	Xinxiang	0.1541	Maoming	0.1274	Heyuan	0.1052	Wuwei	0.0745
Changchun	0.2673	Nanchang	0.1928	Yuncheng	0.1523	Gian	0.1273	Ankang	0.1020	Suihua	0.0740
Linyi	0.2662	Xuchang	0.1923	Pingxiang	0.1515	Mianyang	0.1270	Huludao	0.1018	Liaoyuan	0.0738
Jinan	0.2657	Huzhou	0.1921	Yulin	0.1508	Baishan	0.1267	Mudanjiang	0.1016	Laibing	0.0710
Dalian	0.2650	Tai'an	0.1917	Anshun	0.1496	Benxi	0.1264	Matsubara	0.1011	Haidong	0.0647
Yantai	0.2581	Weihai	0.1912	Xiaogan	0.1495	Lincang	0.1254	Chaoyang	0.1010	Zhongwei	0.0573
Haikou	0.2537	Xingtai	0.1902	Lanzhou	0.1483	Deyang	0.1252	Suining	0.1007		

governments are very low, and it is difficult to cope with the complexity and uncertainty of PPP projects. The low efficiency of the government also increases the transaction cost of PPP contracts, which directly affects the successful implementation of PPPs. Finally, some cities are shrinking cities, the population is in a state of outflow, and the demand for infrastructure and public services tends to decrease. PPPs are a long-term cooperation, in which the operation stage is greatly affected by environmental protection risks, public risks, and insufficient revenue risks in the context of undesirable urbanization.

Discussion

Global experience indicates that PPPs are not a universally suitable model for infrastructure delivery. In other words, PPPs may not be appropriate for all cities and sectors, necessitating careful evaluation and scrutiny before adoption. This comprehensive assessment involves various indicators. Existing research and practice on PPP evaluation have primarily focused on individual projects or policies, with limited studies delving into the suitability of PPPs. To bridge this gap, this study aims to develop an assessment model to quantitatively evaluate PPP suitability in China's cities.

The results corroborate existing studies, showing that economic and financial factors are critical in PPP development, particularly in PPP1.0 phase (Cheng et al. 2021). In general, the developed cities with robust fiscal revenue, the future returns of PPP projects are more assured, increasing the likelihood of project success and attractiveness to the private sector. However, there is often limited interest in adopting the PPP model in more developed cities.

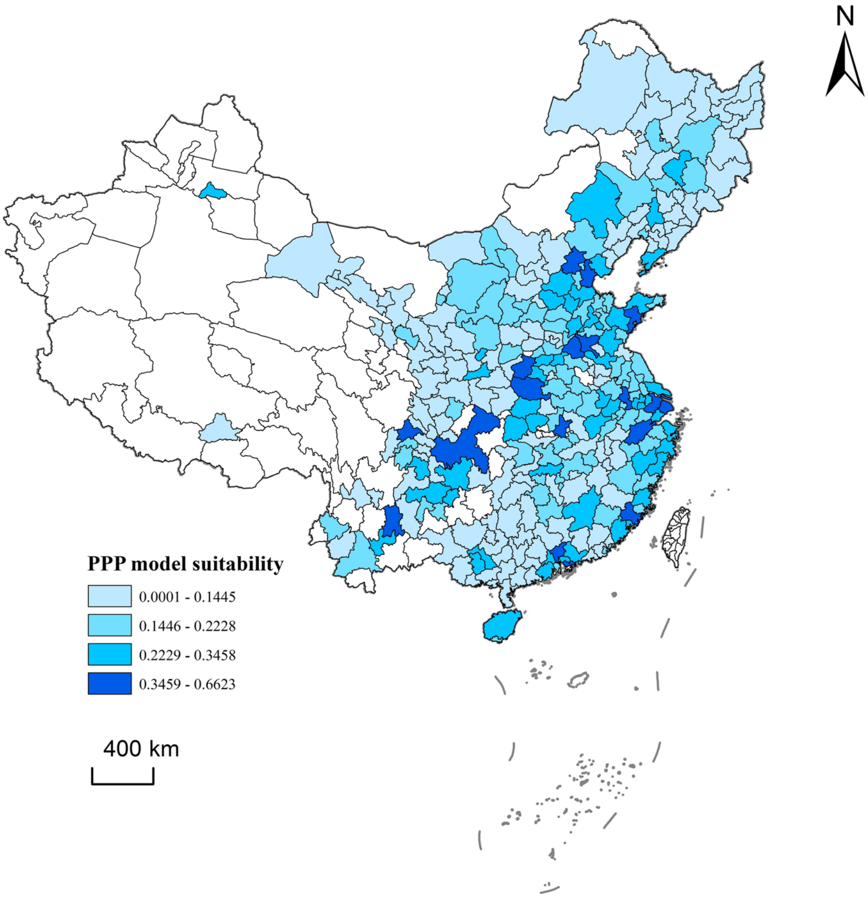

Fig. 2 Spatial pattern of PPP suitability in China.

These conclusions do not imply that less developed cities are not suitable for PPPs. In fact, to stimulate economic growth and meet urban development needs, less-developed may be more inclined to use PPPs for infrastructure delivery (van den Hurk and Hueskes 2017). However, adopting PPPs in these cities requires strict legal compliance and careful review and regulation of PPP projects throughout their lifecycle. Conversely, failure to meet these conditions, or distorting the adoption of PPPs, can lead to negative outcomes, including project failures, damaged government credibility, and increased risk of government debt crises.

The spatial difference of PPPs is an important aspect that cannot be overlooked. A suitability assessment that considers PPP spatial differences reveals significant variation. Under current conditions, most cities in China are not ideally suited for direct PPP adoption. According to the classification in this study, targeted policies or measures are needed for different types of cities. Cities with high PPP suitability should be encouraged to adopt PPPs and standardize PPPs as exemplary models. Those with medium suitability should apply PPPs cautiously and methodically. In cities with low suitability or unsuitability for PPPs, government capacity should be strengthened, and limited PPP projects should be piloted, gradually implementing PPPs based on experience and familiarity with the model. PPPs, as a supplementary model, should be applied within a controlled range and volume.

Conclusions

This study explores a country-based assessment model for evaluating urban PPP suitability. After years of rapid development, China's PPP sector is undergoing a restructuring, with the future direction of PPP development still unclear and uncertain. PF2 in the UK has also seen a hiatus. A global downturn in PPP practice suggests a need for critical reflection and experience sharing in academia. This study not only provides a scientific basis for the sustainable development of PPPs in China, but also enriches the global understanding of PPP governance.

This study has several limitations. Firstly, the choice of indicators may not fully capture all relevant aspects of PPP suitability, potentially impacting the comprehensiveness of the assessment model. Secondly, the acquisition of data was constrained by availability and quality, which may affect the accuracy of the results. Thirdly, the applicability of the assessment model to other countries remains uncertain, as the model requires a high volume of data input.

Future studies should refine and expand the indicators used in PPP suitability assessments to ensure a more comprehensive evaluation by introducing interviews with subject experts and experimenting with the model in other countries. Comparative studies involving different national contexts will help to test and adapt the model's applicability to other countries. Additionally, exploring the dynamic interactions between various factors influencing PPP success can provide deeper insights. Longitudinal studies should be conducted to understand the long-term impacts and sustainability of PPP projects.

We propose several policy recommendations based on our findings. First, in a developing country like China, with its multitude of cities and significant internal variations, the application of PPPs requires a nuanced approach. It is crucial to recognize that PPPs, while not a mainstream infrastructure delivery model, serve as a useful complement. Policymakers should ensure that

PPP implementation adheres to standardization and legal frameworks, avoiding the misuse of PPPs for local or short-term gains, particularly by local governments. Additionally, fostering transparency, accountability, and stakeholder engagement in PPP projects will enhance their effectiveness and sustainability.

Data availability

All data generated or analyzed during this study are included in this published article and its supplementary information files. These materials provide access to the complete raw data for the indicators used in this study and the data sources in the form of URL links.

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Author contributions

Conceptualization: ZC; methodology: ZC, YZ; formal analysis: ZC, YZ; writing/original draft preparation: ZC, HW, YZ; writing/review and editing: YK. All authors actively participated in the writing and editing process. All authors read and approved the final manuscript. Correspondence to YZ and YK.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

Informed consent is not applicable. This article does not contain any studies with human participants performed by any of the authors.

Additional information

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