

Article

Applicability of the International Framework for Eco-Industrial Park in China—Survey and Analysis Based on 17 Case Parks in Jiangxi Province

Yu Shao ^{1,2}, Jingru Liu ^{2,3,*} , Xiuzhi Hua ² , Chinthaka Kularathne ⁴  and Lei Shi ⁵

¹ Henan Institute of Advanced Technology, Zhengzhou University, Zhengzhou 450003, China; shaoyu11@gs.zzu.edu.cn

² State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China; huaxzhi@foxmail.com

³ College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

⁴ Board of Investment, Colombo P.O. Box 1768, Sri Lanka; chinthakak@boi.lk

⁵ School of Resources and Environment, Nanchang University, Nanchang 330031, China; shilei@ncu.edu.cn

* Correspondence: liujingru@rcees.ac.cn

Abstract: Eco-industrial parks, as complex ecosystems at the regional scale, involve multi-dimensional interactions in terms of management, environment, economy, and society in their development. Given their complexity, it is difficult for a single indicator to comprehensively assess their sustainable development status. To promote sustainability and inclusive development of industrial parks, the World Bank Group published “the International Framework for Eco-Industrial Park” as a green evaluation benchmark. This paper examines the applicability of this framework in Chinese industrial parks, focusing on 17 cases in Jiangxi Province supported by the China-Jiangxi Eco-Industrial Parks Project. This study analyzes the indicator composition of the international EIP framework and compares it with the standardization system of eco-industrial parks in China. Through questionnaire surveys and dialogue interviews, this paper analyzed the compliance, practicality, and necessity of implementing the international EIP framework. Quantitative assessment using the analytic hierarchy process and the fuzzy comprehensive evaluation model revealed that the framework is well suited to Chinese conditions, scoring over 80, reaching the “applicability level”. This research provides a scientific basis for park management, advocating for international concepts in park development. It also underscores the importance of a comprehensive framework for park construction, intelligent management strategies, and enterprise empowerment, collectively contributing to sustainable park development and enhanced international competitiveness.

Keywords: eco-industrial park; the international framework for EIP; fuzzy comprehensive evaluation model; applicability analysis



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1. Introduction

Given the rapid evolution of the global economy and the escalating significance of sustainable development, industrial parks (IPs) serve as pivotal regional platforms for concentrated industrial development and resource aggregation, thus facing new challenges and opportunities. The establishment of eco-industrial parks (EIPs) is regarded as an effective strategy for harmonizing environmental sustainability with economic progress [1]. After the successful establishment of the Kalundborg Eco-Industrial Park [2], countries with advanced environmental management such as the United States, the Netherlands [3], South Korea [4], and Japan [5] have also made significant progress in the practice of eco-industrial park development. EIPs refer to a new type of industrial park designed and established according to the requirements of clean production, the concept of circular economy, and the principles of industrial ecology [6], and its concept was first put forward by the American scholar Ernest Lowe [7].

Industrial ecology and industrial symbiosis provide the theoretical underpinning for the establishment of EIPs [8]. Over time, its implications continue to evolve and deepen [9]. The core of EIPs lies in industrial symbiosis, which entails not only pairwise exchanges of materials [10], energy [11,12], and waste [13] but also the establishment of a network through multilateral exchanges among symbiotic units within the park [14,15]. This dynamic fosters innovative and emergent symbiotic relationships [16]. These parks exemplify a spatial agglomeration of industrial symbiosis, wherein co-operation and synergy effects, previously centered on technical solutions, transition to encompass social networks, inter-enterprise, and community relationships due to their geographical proximity [17]. Hence, EIPs transcend mere industrial symbiosis networks, evolving into composite ecosystems that encompass natural, economic, and social subsystems [18]. In China, amid the ongoing urbanization process, numerous industrial parks are progressively transforming into emerging urban zones. These parks are shifting from predominantly serving industrial production functions to incorporating diverse functionalities such as production, residential areas, and ecological features [19]. As an emerging model of industrial development, strategic planning and effective management of EIPs are critical to achieving desired levels of economic, social, and environmental performance [20]. The transformation of traditional industrial parks into EIPs provides a valuable opportunity to achieve inclusive and sustainable industrial development [21]. Furthermore, the practical exploration of EIPs has attracted high attention from international institutions. Since 2012, the United Nations Industrial Development Organization (UNIDO) has been promoting EIPs practices in various countries as part of the Global Resource Efficient and Cleaner Production (RECP) Program [22], which evaluates EIPs in developing countries, involving 33 industrial parks in 12 countries, which formed the basis of the Global Eco-Industrial Parks Program (GEIPP) [23]. The goal of the GEIPP project is to explore the feasibility of EIPs in practice and their long-term benefits by systematically improving resource productivity and optimizing the economic, environmental, and social performances of the parks and their enterprises in general.

1.1. An International Framework for Eco-Industrial Parks

In 2017, aiming to bolster the competitiveness of ecological industrial parks and foster inclusive development, the World Bank Group, UNIDO, and GIZ collaboratively published *An International Framework for Eco-Industrial Parks* [24]. The framework is the first joint international framework on EIPs and addresses a gap in the international understanding of EIPs [25]. This framework focuses comprehensively on the environmental, social, and economic aspects of industrial park management, including specific EIP performance expectations. Common EIP components include a sustainable park management structure; park-level and, where applicable, firm-level resource efficiency and cleaner production; industrial symbiosis and synergies; interactions with the local community and natural environment; spatial planning and zoning; socially acceptable working and living conditions; and collective use of park-level infrastructure, such as utility services and facility management. This framework has been globally implemented in diverse regions, including India, Egypt, Turkey, Vietnam, and others, to enhance the meticulous management and institutional development of local parks [26].

In 2021, following five years of implementation, the World Bank revised the International Framework for Eco-Industrial Parks, Version 2.0 [27], to enhance its applicability and data accessibility. The framework version 2.0 changed the indicators for the four dimensions of management, environment, society, and economy from 51 (18 prerequisites and 33 performance indicators) to 64 (31 prerequisites and 33 performance indicators). Dick et al. evaluated 50 industrial parks in eight developing countries (Colombia, Egypt, Indonesia, Nigeria, Peru, South Africa, Ukraine, and Vietnam) using the International EIP Framework, indicating that parks with low compliance require technical assistance for the development of eco-industrial parks [28]. UNIDO has facilitated the transition of five existing IPs in Vietnam from traditional industrial areas to EIPs through policy

formulation using this framework [29]. An increasing number of countries and industrial parks are striving to establish “standards” or “benchmarks” to ensure the sustainability and inclusiveness of their industrial development.

The development and operation of IPs constitute a complex and diverse process, engaging multiple stakeholders including governments, enterprises, communities, and environmental organizations [30]. These stakeholders play pivotal roles in diverse aspects of park planning, construction, operation, and management [31,32]. The International EIP Framework furnishes crucial tools, guidance, and objectives for the development and transformation of industrial parks [33]. The framework elucidates not only the requirements of parks in park management, environmental protection, social responsibility, and economic benefits but also furnishes self-assessment and improvement directions for all relevant stakeholders of the parks. By adhering to the International EIP Framework, IPs can achieve better balance among the interests of all parties and realize co-ordinated development of economy, society, and environment.

1.2. Analysis of China's EIPs Standard Development

In 1997, the United Nations Environment Programme (UNEP) published a technical document regarding the environmental management of industrial parks [34]. Subsequently, through international co-operation projects, this concept was introduced to the Chinese government, park managers, and scholars, rapidly attracting attention and adoption from China's environmental protection departments. Since 2000, China has steadily advanced the green development and ecological exploration of IPs using a “pilot-demonstration-spread” strategy [35], establishing a standardized, institutionalized, and dynamic model for sustainable development [36]. The policy evolution of Chinese industrial parks' eco-transformation includes the development of national eco-industrial demonstration parks, circular economy parks, low-carbon industrial parks, and green industrial parks [37]. Figure 1 depicts the developmental trajectory of the Chinese national demonstration EIPs standard system. China has refined its management approach and standard system for EIPs through top-down implementation [38]. As of December 2023, a total of 77 parks have been awarded the title of “National Demonstration Eco-Industrial Parks” and 375 parks have been designated as “Green Parks”. Certified eco-industrial parks and green parks demonstrate significantly better performance in terms of environmental pollutant emissions and energy consumption intensity compared to the average level of ordinary IPs [39].

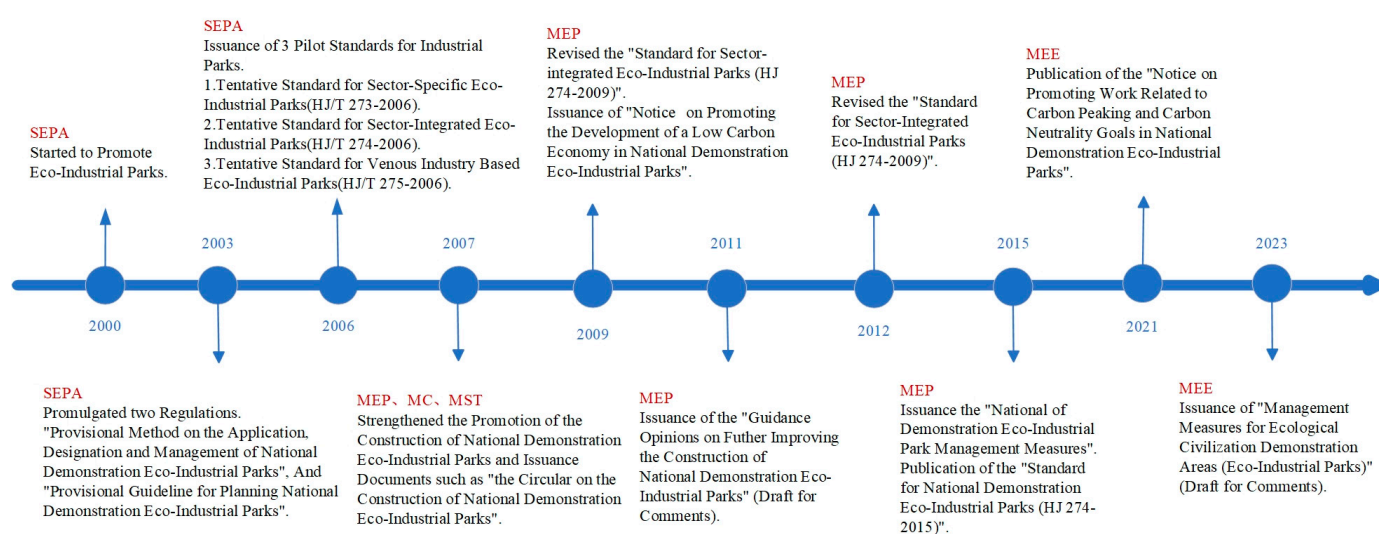


Figure 1. Important nodes and policies for the development of national demonstration eco-industrial parks. Note: SEPA = State Environmental Protection Administration; MEP = Ministry of Environmental Protection; MC = Ministry of Commerce; MST = Ministry of Science and Technology; MEE = Ministry of Ecology and Environment.

While various approaches can be employed to develop and promote EIPs, the establishment of standards and guidelines has proven to be beneficial for fostering EIP development in China. However, the proportion of IPs certified under the standards is still low; this appears to reflect an “elite model” for Chinese EIPs certification, implying that some potentially qualified industrial parks may be excluded from obtaining EIP certification because of quota limitations [40].

In 2020, the World Bank collaborated with Jiangxi Province on a demonstration project for the transformation and upgrading of industrial parks. This initiative aimed to enhance the sustainable development capacity and overall competitiveness of industrial parks in Jiangxi Province. It sought to achieve this by establishing EIP systems and regulatory frameworks aligned with international standards. Notably, this represented the first adoption of the international EIPs framework in China. Jiangxi Province is in the midst of rapid industrialization and is the only province in China designated as both a national ecological civilization demonstration area and a national pilot for realizing the value of ecological products. It serves as a model area for building a beautiful China. In order to promote the green and ecological development of industrial parks, Jiangxi Province initiated the establishment of ecological industrial parks across the province as early as 2008. Based on the national standards for ecological industrial demonstration parks, a provincial assessment and evaluation index system was established. Jiangxi’s industrial parks have a solid foundation and management mechanism in the construction of ecological industrial parks.

In order to illustrate and assess this framework’s applicability and feasibility to industrial parks, we applied these indicators to 17 parks in Jiangxi Province. This article uses a combination of qualitative and quantitative analyses to develop the following research content: (a) combining through the existing eco-industrial park evaluation index system in China, comparing it with indicators of the international eco-industrial park framework, and analyzing the differences in the evaluation of eco-industrial parks at home and abroad and the reasons for them; (b) with expert interviews and assessed compliance, feasibility, necessity, and applicability of the prerequisites and performance indicators in the international eco-industrial park framework through expert interviews and questionnaire surveys; (c) providing empirical evidence and theoretical support for the improvement of China’s eco-industrial park evaluation index system and policy system as well as for the academic research of the international eco-industrial park framework.

2. Materials and Methods

2.1. Questionnaire Design and Collection

During the process of assessing the applicability of indicators within the international EIP framework, it was found that some evaluation indicators required data that were not typically included in the conventional statistical scope of Chinese parks. As a result, these indicators could not be obtained using conventional data sources and could only be qualitatively assessed through on-site interviews and surveys [41]. To address this issue, we conducted in-depth investigations in 17 comprehensive industrial parks in Jiangxi Province, conducting two rounds of social surveys. To begin with, we conducted a pilot test with a small group (4 case parks) of respondents to identify any potential issues with question clarity, wording, or response options. Based on the feedback received during the pilot test, adjustments were made to optimize the questionnaire’s effectiveness.

During the research process, information and data were collected through expert talks and questionnaires. Three to five experts in the field of industrial park research chaired the meetings to understand the development of each park and to introduce in detail the relevant contents of the international EIP framework. Additionally, we utilized the online questionnaire survey platform to collect data, effectively improving the responsiveness of respondents and the accuracy of the data collected [42]. Industrial parks involve various stakeholders such as government institutions, industrial park operators and managers, firms located in industrial parks, employees, and residents, each with different demands and perception. This diversity determines the need for comprehensive balance in managing

the interests of all parties involved [43]. Therefore, the interviewees included departments of economic development, ecology and environmental protection, planning and construction, human resources and social security, statistics of the park, directors of production and operation of enterprises, heads of staff management, and representatives of employees and residents.

The survey respondents are divided into three categories: park management, enterprises, and employees and community residents, according to the different subjects examined in the 64 indicators in the international EIP framework, involving 48, 12 and 4 indicators. Therefore, three sets of questionnaires were designed for this study, as detailed in Table 1. A total of 113 questions were formulated according to indicators, 91 questions were included in the questionnaire targeting the park's management committee, and the first question is a basic information multiple-choice question, which automatically jumps to the relevant category based on the work department selected by the respondent, e.g., those who select the environmental protection department will answer the questions in the environment category. Additionally, the remaining 90 questions comprised 45 objective factual questions (compliance, assessing whether the current status of the park meets the requirements of the international EIP framework) and 45 subjective evaluation questions (feasibility, reflecting respondents' perceptions of the availability of data on implementing the indicators at the park level, as well as the necessity of these indicators as evaluation options for China's eco-industrial park construction). During the second round of research, 90 questions were simplified to 38; these questions were scored using a Likert 5-point scale to represent the evaluation results. The detailed contents of the questionnaire are provided in the Supplementary Materials.

Table 1. Design and collection of questionnaires.

Questionnaire Number	Stakeholders	Categories	Number of Questionnaire Topics	Type of Topic	Number of Valid Questionnaires
①	Government Institutions, Operators and Managers	Park Management, Environmental, Social, Economic	91 39	Objective Factual Questions, Subjective Evaluation Questions	119
②	Firms located in Industrial Parks	Environmental, Social, Economic	16	Objective Factual Questions	60
③	Employees and Residents	Social, Economic	6		79
Total			113		258

2.2. Compliance Levels of EIP Prerequisites and Performance Indicators

According to the EIP assessment tool provided by UNIDO, each of the prerequisites and performance indicators in the international framework for EIP is rated as “fully compliant”, “partially compliant”, “to be confirmed”, or “non-compliant”. The formula for calculating the EIP performance level score is as follows: $(\text{Number of “fully compliant” indicators} + \text{Number of “partially compliant” indicators} \times 0.5 + \text{Number of “to be confirmed” indicators} \times 0.5) / (\text{Total number of indicators})$ [28].

To ensure the accuracy of the results, the rating of “partially compliant” is only applied to prerequisites and not to performance indicators. This is because prerequisites are mostly qualitative descriptions, comprising multiple conditions that industrial parks need to meet. During this study, it was found that the park had successfully implemented some but not all of the prerequisites. In such cases, a rating of “partially compliant” is assigned with a weight of 0.5 during scoring. “Partially compliant” ratings help to understand which themes the park has already addressed within the international EIP framework and which areas require further effort to fully meet the conditions. When rated as “to be

confirmed”, it indicates that the park lacks statistical data for this particular theme and its actual performance remains unknown. Therefore, a weight of 0.5 is also assigned in this case.

2.3. AHP–Fuzzy Comprehensive Evaluation Method

In light of the survey results and the decision-making issues faced in this study, namely the analysis of the applicability of the international eco-industrial park (EIP) framework in China, a comprehensive decision-making process integrating qualitative analysis and quantitative calculation is required. This process entails multiple indicators, levels, and objectives, along with incomplete information and numerous human factors, making it challenging to objectively and scientifically analyze. Hence, the selection of an appropriate evaluation method is crucial [44]. The analytic hierarchy process (AHP) is commonly used to solve complex decision-making problems with multiple objectives, and it is also widely applied to determining the weights of evaluation indicators. The fuzzy comprehensive evaluation method (FCEM) is a comprehensive evaluation approach based on fuzzy mathematics. It transforms qualitative assessments into quantitative evaluations using the theory of membership degrees, effectively addressing ambiguous and difficult-to-quantify issues. Therefore, this paper opts for the AHP-FCEM to assess the applicability of the international EIP framework. As shown in Figure 2, we will analyze the applicability level of each indicator in the framework from three dimensions: compliance, practicality, and necessity.

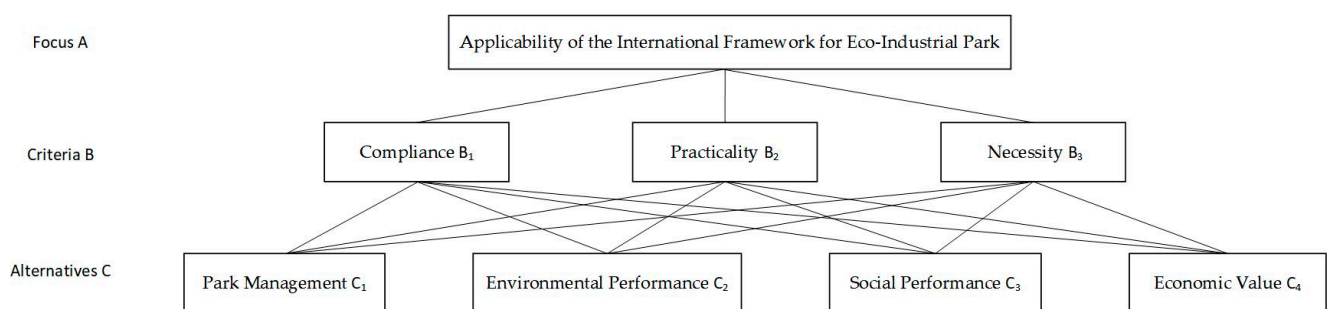


Figure 2. Hierarchy of applicability analysis dimension.

According to the established hierarchical model, the experts who participated in the symposium constructed a judgement matrix A_{ij} using the 1–9 scale method, calculated the weights W_i , and conducted a consistency check in Tables 2 and 3.

Table 2. The consistency check results and calculated weights of the focus.

B-A	W_i	CR	$\lambda_{\max}$	Consistency Check
B ₁	0.1005	0.0053	3.0055	pass
Practicality B ₂	0.4330			
Necessity B ₃	0.4665			

Notes: CR: consistency ratio, $\lambda_{\max}$: maximum eigen value of matrix A.

Table 3. The consistency check results and calculated weights of the focus and criteria.

W_i	B ₁	B ₂	B ₃	A
C ₁	0.1723	0.2369	0.173	0.2006
C ₂	0.6024	0.5765	0.6436	0.6104
C ₃	0.0381	0.119	0.1131	0.1081
C ₄	0.1871	0.0676	0.0704	0.0809
$\lambda_{\max}$	4.2718	4.1752	4.1475	-
CR	0.0816	0.0656	0.0552	0.0624
Consistency Check		pass		

When analyzing the results of the questionnaire, a set of evaluation criteria is formed to classify the evaluation levels into five grades, denoted as $V = (V_1, V_2, V_3, V_4, V_5) = (20, 40, 60, 80, 100)$, representing different levels of assessment [45]. Once the evaluation criteria set is established, standardization and grading of indicators are achieved through membership function calculation. Fuzzy mathematics calculates the correlation between each indicator and each level of the evaluation criteria set using membership functions, enabling the determination of the level to which each indicator belongs based on the magnitude of correlation. The membership function calculation also achieves the standardization of the numerical values of each indicator, thereby rendering them dimensionless. In this study, the weighted average multiplicative-bounded operator is selected to establish the affiliation function matrix $R_i = (R_{i1}, R_{i2}, \dots, R_{im})$. R_i represents the membership degree of the i th indicator in the evaluation factors to each $V_1, V_2, \dots, V_5$ in the set of evaluation comments, and the formula is:

$$R_{ij} = \frac{\text{number of people choosing } V_i \text{ grade for the } i\text{th indicator}}{\text{total number of people participating in the evaluation}}, \text{ where } j = (1, 2, \dots, m) \quad (1)$$

Based on the obtained evaluation matrix R for each level, the fuzzy arithmetic calculation is carried out with the weights W_i of the evaluation indexes at all levels, and the judgement matrix B_i at all levels is obtained, and the formula is as follows:

$$B_i = W_i \cdot R_i \quad (2)$$

After obtaining the fuzzy evaluation results at all levels, based on the idea of “single-indicator quantification, multiple-indicator integration” [29], the evaluation set is combined with defuzzification calculation for each indicator layer and criterion layer, and the quantitative results of the comprehensive evaluation C_i are obtained; the formula is:

$$C_i = B_i \cdot V \quad (3)$$

3. Results and Discussion

3.1. Comparative Analysis of Chinese and International EIP Standards

This article counts the indicators in National Demonstration Eco-Industrial Parks (HJ 274–2015) and Green Park Evaluation Requirements. To compare them with the international EIP, the article categorizes China’s EIP indicators into four dimensions based on the international framework for EIP: environmental, economic, park management, and social. A comparison between China’s EIP indicators in Figure 3a and those of the international framework for EIP is presented in Figure 3b. This article adopts tree-map to illustrate the proportions of each dimension [46]. Tree-map consists of nested sets of rectangles, with the area of each smaller rectangle indicating the proportion of its corresponding sub-item. Larger rectangles signify a greater proportion of the sub-data within the entire dataset. Additionally, Table 4 illustrates the comparison of indicators between the domestic and foreign standards, displaying the percentage of indicators for each category in both contexts.

Table 4. Percentage of the number of indicators in different categories of eco-industrial park standards in China and abroad.

Categories	Social	Park Management	Economic	Environmental
China’s EIP Standards indicators	6.10%	19.51%	24.39%	50.00%
The international framework for EIP indicators	21.87%	14.06%	17.19%	46.88%

Through benchmarking indicators from domestic standards against those outlined in the international framework for EIP, we identify both commonalities and disparities. As depicted in Figure 3, while domestic standards exhibit clear quantitative indicators, the

indicators outlined in the international EIP framework are more elaborate yet also more comprehensive. Domestic standards primarily emphasize efficient resource utilization, pollution control, environmental management, and economic development [47]. However, compared to the international framework for EIP, they somewhat lack in social indicators, covering only 2–3 out of the 14 specific indicators outlined internationally.

Social performance within the international framework for EIP encompasses two main facets. Firstly, it ensures the fulfillment of workers' working conditions and basic human rights within the park, including aspects such as gender equality, reasonable working hours, occupational health and safety, vocational training opportunities, grievance mechanisms, personal security, and the provision of public infrastructure to meet residents' needs. Secondly, eco-industrial parks are required to maintain regular engagement with community residents through dialogues and outreach activities, while also mandating that companies fulfill their social responsibilities.

In terms of economic indicators, unlike China's EIP standards, the international framework shifts focus away from assessing the economic value generated by the park and its industrial structure, instead emphasizing the importance of eco-industrial parks in bolstering support for local businesses and small and midsize enterprises (SMEs) and generating local employment opportunities.

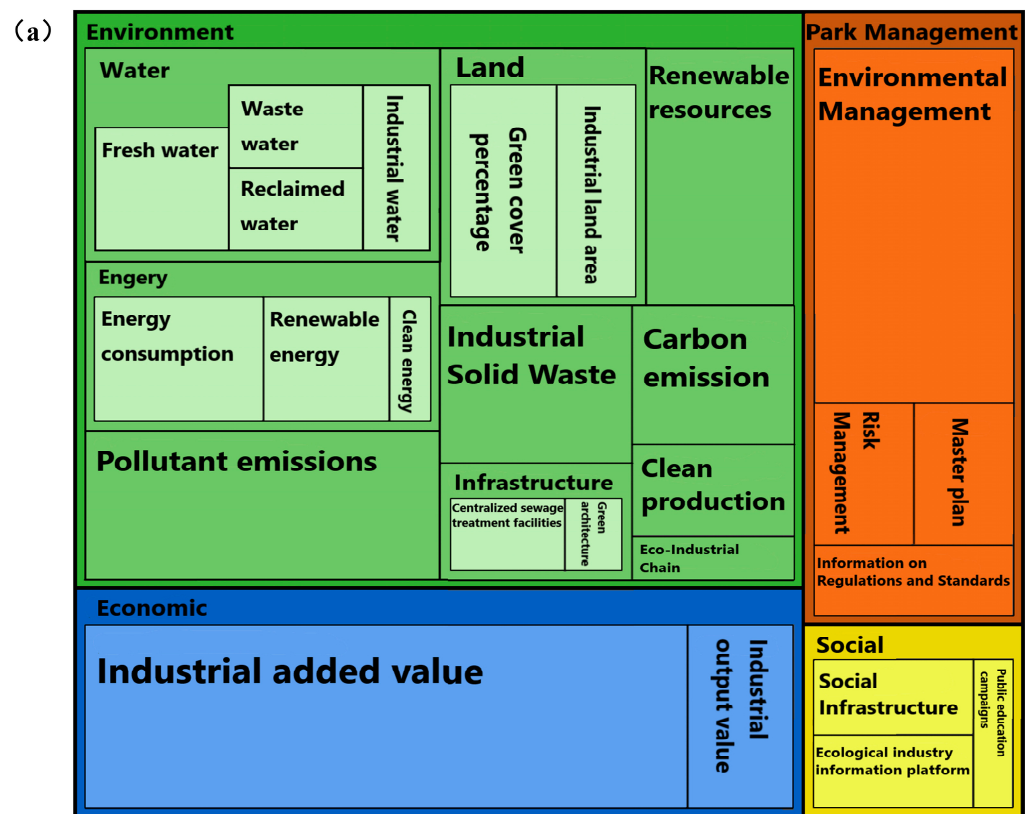


Figure 3. Cont.

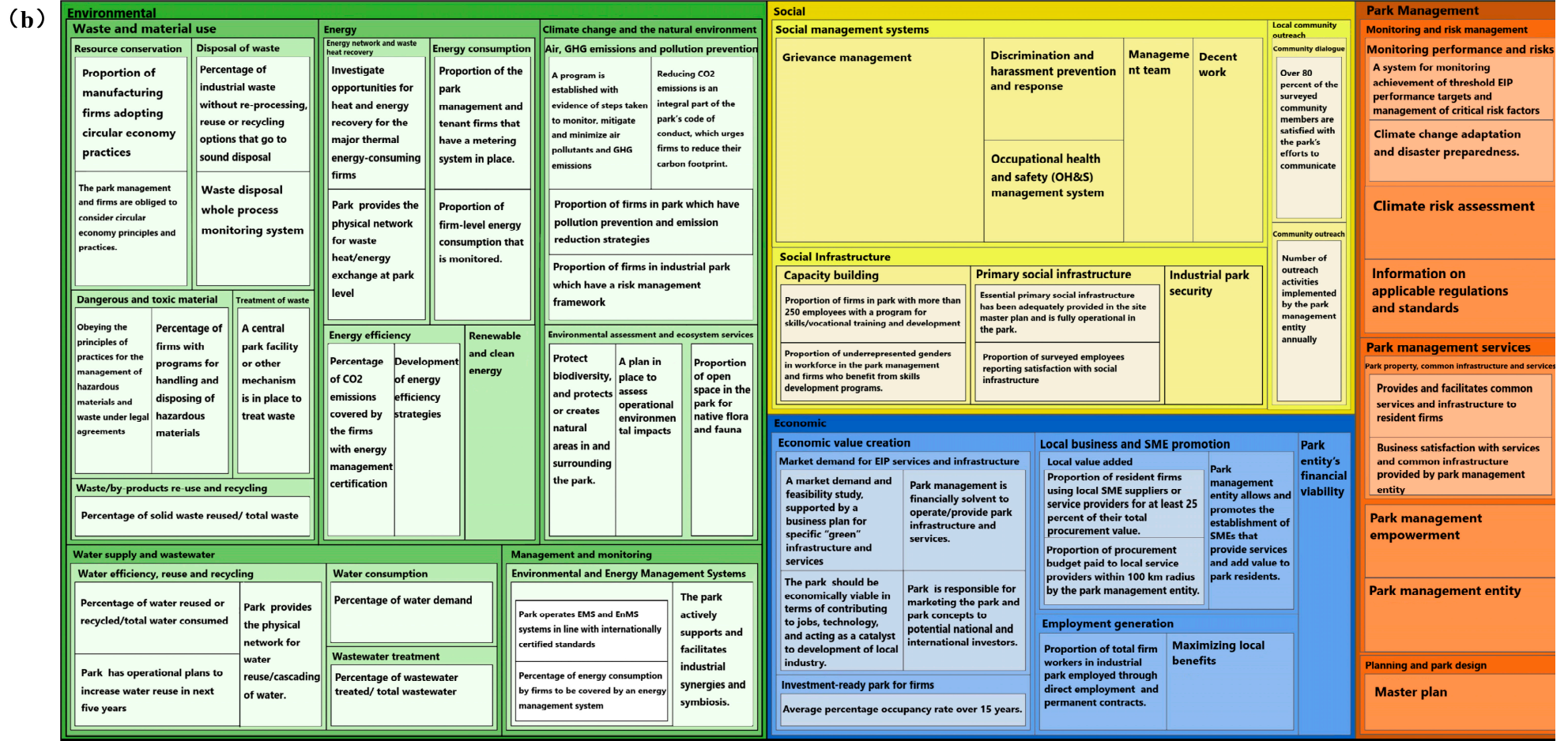


Figure 3. A comparative analysis tree-map between China's EIP indicators and those of the international framework for EIP. (a) Specific content of the evaluation index of eco-industrial parks in China, (b) Specific content of the international EIP framework.

3.2. Evaluation Results of Compliance Levels

This study conducted two rounds of social surveys. In the first round of the survey, only the park management departments, namely the management committees of various development zones, were investigated. The results were 32 fully met the requirements of the international EIP framework, 10 partially met the requirements, 19 pending confirmation, and 3 that did not meet the requirements. Calculated from the formula in Section 2.2, the compliance level of the international EIP framework was 72.66. Analyzing the 19 indicators pending confirmation revealed that the focus of the evaluation indicators for China's eco-industrial parks is on the overall ecological efficiency of the park and the level of park management [48]. In contrast, the international EIP framework indicators require that enterprises with more than 250 employees within the park focus on the work environment of employees, the social infrastructure provided by the park, the satisfaction with park promotional activities, and the development and benefits of professional skills for female employees. Therefore, a second round of questionnaire surveys was conducted for these indicators.

Through the questionnaire survey, this study determined the compliance status of 14 out of the 19 "to be confirmed" indicators, as shown in Table 5, with 13 indicators meeting the standards.

Table 5. Results of the International EIP Framework Indicators.

No.	Categories	The International EIP Framework Indicators	Target Value	Actual Value
1	Park Management	Proportion of firms in the industrial park to have signed a residency contract/park charter/code of conduct.	100%	100%
2		Proportion of satisfied resident firms with regard to the provision of services and common infrastructure by the park management's entity out of total respondents	75%	91.67%
3	Environmental	Proportion of firms in industrial park which have a risk management framework	30%	95.83%
4		Proportion of firms in park which have pollution prevention and emission reduction strategies to reduce the intensity and mass flow of pollution/emission releases which exceed national regulations	50%	66.67%
5	Social	Proportion of firms with more than 250 employees that have an OH&S management system in place	75%	79.17%
6		Proportion of firms with more than 250 employees that have a code of conduct system in place to deal with grievances	75%	100%
7		Proportion of firms with more than 250 employees that have a harassment prevention and response system in place	75%	100%
8		Proportion of firms in park with more than 250 employees with a program for skills/vocational training and development	75%	100%
9		Proportion of surveyed employees reporting satisfaction with social infrastructure.	80%	87.34%
10		At least 80 percent of women and 80 percent of men of the surveyed workers agree that each of these decent work criteria are met	80%	77.2%

Table 5. Cont.

No.	Categories	The International EIP Framework Indicators	Target Value	Actual Value
11	Economic	Over 80 percent of the surveyed community members are satisfied with the park's efforts to communicate	80%	81.73%
12		Proportion of underrepresented genders in workforce in the park management and firms who benefit from skills development programs	50%	90.91%
13		Proportion of resident firms using local SME suppliers or service providers for at least 25 percent of their total procurement value.	25%	29.17%
14		Proportion of total firm workers in industrial park employed through direct employment (that is, not employed on a fee-for-output basis or provided through a labor supply firm) and permanent contracts.	30%	62.03%

In the second round of the survey, questionnaires were also distributed to enterprises, employees, and community residents within the park. According to the field research, expert interviews, and questionnaire survey statistics of 17 case parks in Jiangxi conducted in this study, as shown in Figure 4, there were 46 indicators that met the standards, 10 that partially met the standards, 3 pending confirmation, and 5 that did not meet the standards. The compliance level was 82.03. Dick et al. evaluated 50 industrial parks in eight developing countries based on the international EIP framework, with an average performance level score of 58 [28]. Compared to other developing countries, the compliance level of the case parks in Jiangxi Province is significantly higher.

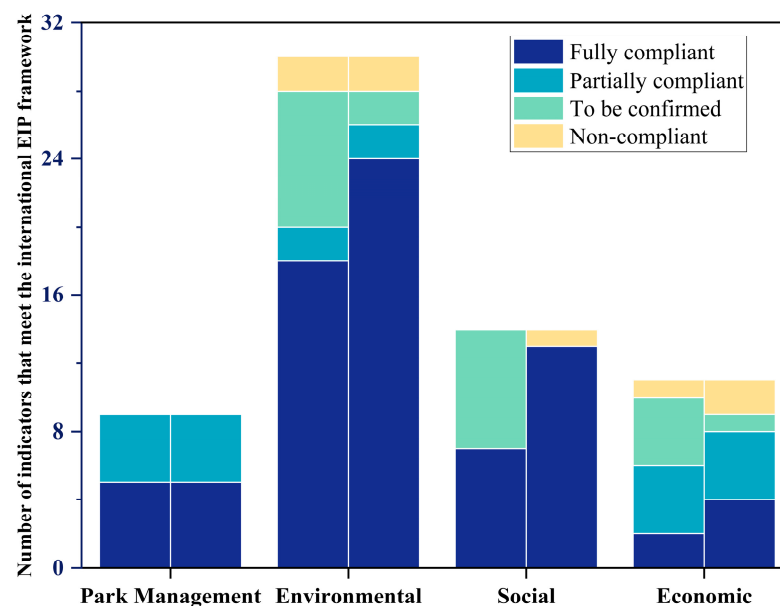


Figure 4. Statistical chart of Jiangxi case park compliance.

The 46 indicators that fully met the standards accounted for 71.88% of the total number of indicators. Under policy guidance, industrial parks in Jiangxi Province have achieved a comprehensive transformation from initially attracting investment with policy incentives and focusing on single-element economic development to later emphasizing the co-ordinated development of multiple elements, including economy, environment, and society. Additionally, during their development, the industrial parks have focused on multi-dimensional management involving economy, environment, and society, such as wastewater treatment, intensive land use, industrial clustering, transformation and

upgrading, and integration of industry and city. These efforts have provided a scientific basis and technical support for the development of Jiangxi Province's industrial parks, contributing to the sustainable development and ecological balance of the parks. At the same time, with the requirements for high-quality green development, the parks have further focused on innovative development, circular transformation, all-element production, integrated energy systems, and low-carbon development research and practices, which have also promoted the achievement of various indicators in the industrial parks.

The 10 indicators rated as “partially compliant” involve three categories: management, environment, and economy. These indicators cover comprehensive management aspects from monitoring performance and risks to market demand, including climate risk assessment, strategic formulation of overall planning, real-time follow-up of management and monitoring, environmental assessment and ecological protection of ecosystem services, as well as market demand analysis for eco-industrial park services and infrastructure. The analysis suggests that the precision management of parks varies depending on park conditions and management levels. Some parks, with advanced concepts, scientific planning, and efficient teams combined with modern technological methods, have achieved excellent results in precision management. However, other parks, due to outdated management concepts, single methods, or insufficient team capabilities, have shown poor results in precision management. To improve the precision management level of parks, it is necessary to focus on innovation in concepts, scientific planning, technology application, and team building.

The five indicators that completely failed to meet the standards fall into the categories of environment, economy, and society. The environmental indicators require the establishment of a physical network for waste heat or energy exchange at the park level and assisting enterprises in connecting to this network. They also involve investigating measures taken by the park to protect the biodiversity of flora and fauna within the park and evaluating the ecosystem service functions at the park scale. The surveyed parks indicated that they have not yet initiated work related to these two environmental indicators. The economic indicators are two criteria aimed at promoting the development of small and medium-sized enterprises (SMEs). SMEs are a crucial part of the industrial symbiosis network, and the neglect of SMEs by the parks reflects that many parks are still in the development process and lack a complete symbiotic network. The social indicator, as shown in Table 5, is the “proportion of employees satisfied with the employment environment and welfare income”, which did not meet the international EIP framework requirements. However, the result of 77.2% is only slightly below the target value of 80%.

3.3. Analysis of the Applicability of International EIP Indicators to Industrial Parks in Jiangxi Province

According to the multidimensional analysis results of the case parks in Jiangxi Province using the fuzzy comprehensive evaluation model, the applicability score of the international EIP framework in Jiangxi is quite good at 82.03, reaching the “applicable level”. Specifically, the quantitative results of the four categories of indicators required by the international EIP framework in terms of current compliance levels, practicality analysis, necessity analysis, and applicability analysis dimensions are illustrated in Figure 5. Except for the economic category, the scores for the applicability of the indicators in the international EIP framework are all above 80 points. This indicates that stakeholders in the parks generally recognize the feasibility and necessity of applying the international EIP framework in domestic parks.

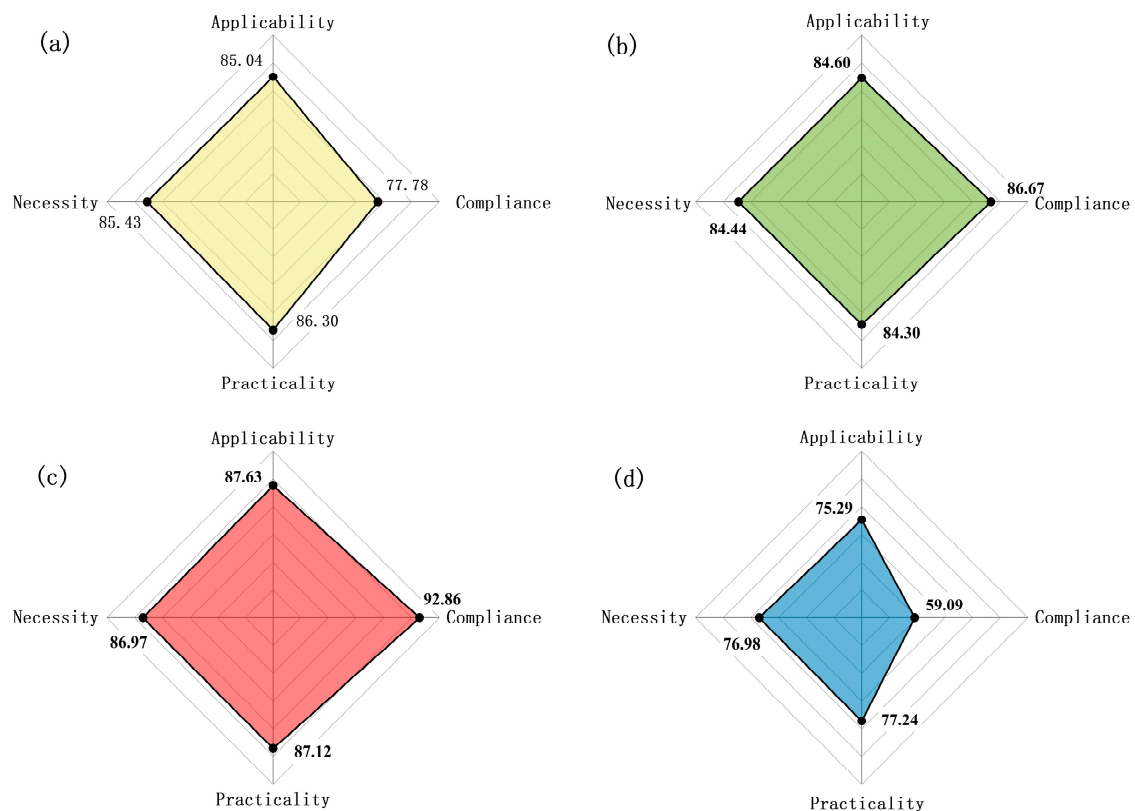


Figure 5. Result of compliance levels, practicality, necessity, and applicability about four dimensions. Note: (a) Park Management, (b) Environmental Performance, (c) Social Performance, and (d) Economic Value.

3.4. Park Management

Park management indicators scored above 80 in three dimensions, with the highest score in “Practicality”. The high score is attributed to the significant consistency between the International EIP Framework and Chinese park inspection standards. Although many prerequisites proposed in the International EIP Framework are not explicitly included in Chinese standards, they are mandatory requirements for constructing Chinese industrial parks that require planning approval from government departments.

The understanding and implementation of policies by park management institutions during the construction of eco-industrial parks determine the overall ecological development of the park. Currently, Chinese standards still limit supervision of park management to the formulation and management of plans. In contrast, the assessment criteria of the International EIP Framework are more comprehensive, including the understanding of local/national laws and regulations and international standards by park management personnel, as well as indicators of enterprise satisfaction with the services and infrastructure management provided by the park. This emphasizes the importance of management and monitoring in the entire ecological park construction process.

3.5. Environmental Performance

Environmental indicators scored above 80 in the dimension of the current assessment. Through comparative analysis of Chinese and international EIP standards, environmental performance requirements also constitute the largest proportion of the standards for parks in China and have the greatest similarity with the international EIP indicators. The difference is that Chinese park environmental standards focus primarily on outcome-oriented results, particularly emphasizing quantifiable results such as overall reduction in pollutant emissions and improvement in resource utilization rates, judged by specific numerical increases or decreases to determine compliance and improvement levels. In contrast, the

International EIP Framework imposes dual requirements on environmental performance and the intermediate processes to achieve it. Besides demanding outcomes in environmental management, it also requires parks to establish sound intermediate processes related to pollution control and resource efficiency enhancement, including environmental infrastructure construction and environmental management methods, to help parks and businesses achieve environmental protection and continuous improvement goals. Feasibility and necessity scores obtained from the research both exceeded 80, indicating that stakeholders in the park have considerable confidence in the implementation of the International EIP Framework in the park. From the results, the various stakeholders of the park are relatively confident about the implementation of the international EIP framework in the park.

3.6. Social Performance

Based on preliminary investigations, it was anticipated that the applicability score of social indicators would be relatively low. However, the actual results show that the scores in all four dimensions are greater than 80; even the compliance scored 92.86. An analysis of the reasons suggests that some requirements in the International EIP Framework, although not explicitly listed in the standards of various Chinese parks, are still applicable to the construction of ecological industrial parks in China. For example, the International EIP Framework requires that “parks should provide basic social infrastructure and services, such as lighting systems, security systems, nighttime transportation, medical and educational services”, which are essential conditions in the planning and development process of domestic parks. The underlying logic of social performance indicators is a test of park infrastructure construction and public services. In the past, the development of parks mainly focused on meeting the basic infrastructure requirements of industries. However, in recent years, to improve the development of industrial parks, China has vigorously promoted the concept of urban–industrial integration. By providing differentiated and diversified service products around the demands of enterprises, industrial workers, and local residents and by enhancing the level of internal public service and facilities in industrial parks, the business environment of industrial parks has been optimized, thereby enhancing the core competitiveness of industrial parks.

3.7. Economic Value

The scores for all four dimensions of the economic indicators are low, especially the compliance of only 59.09. Compared to the indicators in the other three categories, the scores in each dimension are relatively lower. An analysis of the reasons suggests that the evaluation system for domestic parks mainly targets park management committees, with indicators largely describing ecological efficiency. The focus is relatively narrow compared to the International EIP Framework. Park management personnel are less familiar with the International EIP Framework’s examination of the synergy between ecological industrial parks in improving resource and energy efficiency and economic development, particularly regarding support and promotion for local SMEs. Parks often implement supportive policies for enterprises, but there is no clear statistical method or data quantification of the economic benefits derived from these policies. Hence, the results of the economic indicators’ applicability analysis are relatively poor.

The perspectives on measuring the economic performance of industrial parks differ between Chinese standards and the International EIP Framework. China park standards prioritize numerical values of overall economic output, emphasizing industrial output, such as business income, the output value of high-tech industries, the added value of large-scale enterprises, and growth rates, as well as the added value of green industries. In contrast, the International EIP Framework does not measure the economic performance of industrial parks directly. Instead, it emphasizes that EIPs should drive local employment during the construction process and create opportunities for the development of SMEs. It underscores the role of EIP development in promoting local economic development and the socio-economic impact on population welfare.

4. Conclusions and Recommendations

4.1. Conclusions

As a composite ecosystem at the regional scale, the construction of eco-industrial parks is a continuously advancing process. This paper compares the indicators of the international EIP framework with China's eco-industrial park standard system, concluding that the international framework deepens and enhances the concept of eco-industrial parks. It can serve as a reference and guide for park construction. In future industrial park construction, more emphasis should be placed on the integrity, systematic nature, and co-ordination of the composite ecosystem. On one hand, it is necessary to improve environmental management systems, enhance resource utilization efficiency, reduce pollutant emissions, and ensure the environmental performance of industrial parks. On the other hand, attention should be paid to enhancing ecological functions, strengthening biodiversity protection, and improving ecosystem services, making industrial parks a model of harmonious coexistence between humans and nature.

The objective assessment of the environmental, economic, and social performances following the construction of industrial parks in China is an issue of collective concern among multiple stakeholders. This study, based on the industrial park renovation and upgrading project conducted by the World Bank and Jiangxi Province, applies the International Framework for Eco-Industrial Parks to evaluate the performance of 17 parks in Jiangxi Province. The differences between Chinese and international standards mainly stem from the different assessment methods rather than reflecting flaws in China's industrial park regulatory framework. Parks typically do not collect data beyond what is stipulated by national, provincial, or municipal regulations. Therefore, although parks may lack the data required to meet certain indicators of the international EIP framework, this does not mean that the parks fail to meet the international framework's requirements.

This paper quantitatively calculates the applicability level of the international EIP framework in Jiangxi Province using the AHP-fuzzy comprehensive evaluation method from three dimensions: current status evaluation, feasibility, and necessity. The overall applicability level is 82.38, with feasibility at 82.56 and necessity at 82.39. This indicates that, in the development process of industrial parks in Jiangxi Province, significant achievements have been made in related laws and regulations, park planning, environmental management, and social governance. These aspects are basically in line with the requirements of the international EIP framework, and the application of the international EIP framework is generally recognized by the stakeholders of the industrial parks.

4.2. Recommendations

Eco-industrial parks are a systematic solution for regional ecological construction. The international EIP framework emphasizes the comprehensive competitiveness of parks. This study suggests strengthening top-level design and establishing a comprehensive institutional framework for the ecological construction of industrial parks.

Enhancing the intelligent and refined management of industrial parks is crucial. In recent years, China's industrial parks have also been facing new issues of digital transformation. Building an efficient and sustainable park data resource system, establishing a big data platform for the park, integrating multi-source data, and mining data value are crucial for promoting intelligent decision-making and precise management for the sustainable development of the parks.

To fulfil the main role of enterprises in the park, the international EIP framework emphasizes the importance of local SMEs' participation and socio-economic performance. However, actual results show that the role of enterprises is limited, with the government still assuming the main responsibility. This paper suggests that the government establishes special funds and conducts publicity and education to encourage SMEs to actively participate in the construction of eco-industrial parks, enhance their ecological management capabilities, and increase environmental awareness, thereby realizing the role of enterprises as the main entities in construction.

4.3. Recommendations for Further Work and Research Limitations

This study currently focuses mainly on the applicability of the International EIP Framework in 17 development zones in Jiangxi Province. Although somewhat representative, it is limited by the geographical scope and cannot fully reflect the development status of EIPs in China. Therefore, future research will focus on expanding to a nationwide scope, selecting parks from different regions and development levels to study the applicability of the international EIP framework. This will allow for a comprehensive assessment of its universality and effectiveness in China, providing more precise and scientific recommendations and guidance for the optimization and development of industrial parks.

Supplementary Materials: It contains specifics of the three questionnaires in Section 2.1. The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su16114635/s1>.

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