ENVIRONMENTAL PRACTICE AND ITS EFFECT ON THE SUSTAINABLE DEVELOPMENT OF ECO-INDUSTRIAL PARKS IN CHINA

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ABSTRACT

After more than a decade of development, eco-industrial parks (EIPs) have made significant progress in saving resources and protecting the environment in China. Meanwhile, many problems have emerged, such as poor stability, poor profitability and weak eco-industrial chains, which have impeded the EIP's sustainable development. Faced with variable environmental practices and limited resources and capital, EIPs need to address suitable environmental practices seriously to configure resources reasonably and ultimately realize sustainable development. Therefore, based on an analysis of the elements of environmental practice and sustainable development level, this article aims at identifying those environmental practices that can improve the sustainable development level of EIPs and to analyze the impact of those different environmental practices on the sustainable development level of EIPs using factor analysis and analytic hierarchy process. The results could provide theoretical guidance and reference for decision-making to Chinese government and administration committees of EIPs for choosing and implementing environmental practices.

Keywords: eco-industrial parks (EIPs), environmental practice, the sustainable development level.

1 INTRODUCTION

Eco-industrial parks (EIPs) are the third-generation industrial parks, following the economic and technological development zone and high-tech park. An EIP is an important practical means of implementing sustainable development [1,2]. EIPs maximize resource utilization and minimize waste emission by converting linear production processes into closed-loop processes that divert upstream waste outputs to the raw material inputs needed by downstream producers; therefore, EIPs both reduce the burden on environmental resources and produce economic benefits, a double efficiency, which is their core principle [3].

Since the early 1990s, developed countries, such as the United States and Canada, began to promote EIP projects. By the late 20th century, more than 20 EIPs had been established in developed countries [4] and had achieved remarkable results in resource conservation, waste recycling, energy cascade utilization and water recycling and other practices. Economic and social benefits have followed from the effective protection of the ecological environment as well [5]. In 1999, China began to construct an Eco-Industrial Park Demonstration Garden, and by September 2008, 27 National Eco-Industrial Park Demonstration Gardens had been approved by Chinese government [6]. Through industrial symbiosis, by-product exchange and other processes, representative EIPs, such as Tianjin Economic Technological Development Zone and Guigang National Eco-industrial Demonstration Park, have been built and have already achieved a high level of the sustainable development.

In fact, Chinese Government provides great importance to the implementation of environmental practices during the construction of EIPs, such as making relatively comprehensive policies and regulations, and providing money and technical support. However, with the continuous development of EIPs, many problems have emerged, such as poor stability, poor profitability, policy objectives dislocation and weak eco-industrial chains. Specifically, poor stability, defined as 'vulnerability in the composition, structure and function of EIP', impairs EIPs' product exchange [7]; poor profitability implies that EIPs have no enough capitals to update equipment, introduce new

technology, raise management level and so on [8]; policy objectives dislocation refers to the EIPs' actual functions disjointed with the initial design target, which illustrates the EIP design is failing [8]; weak eco-industrial chains mean that the ecological industry chains of EIPs is not closed-loop, lacking exchange of by-products or waste, which weakens the environmental sustainable development of EIPs [1]. These problems have seriously impeded the sustainable development of EIPs. Facing changing environmental practices and limited resources and capitals, EIPs need to choose environmental practices to configure resources reasonably and ultimately realize sustainable development. Therefore, based on an analysis of the elements of environmental practices and sustainable development level, this article aims at identifying those environmental practices that will help EIPs improve their sustainable development level and to analyze the influence of those different environmental practices on the sustainable development level using factor analysis and analytic hierarchy process. The results will provide theoretical guidance and reference for decision-making to Chinese Government and administration committees of EIPs in choosing and implementing environmental practices.

This article proceeds as follows: Section 2 is the literature review. Section 3 begins with the development of a questionnaire followed by the samples. Section 4 describes the methodology and data analysis in detail. Section 5 presents the results. The conclusions are presented in Section 6.

2 LITERATURE REVIEW

2.1 Sustainable industrial development

The idea of sustainable development is first put forward in 1972. Since then, more than 100 kinds of the definition of sustainable development were proposed. But the most widely accepted and the most influential definition was put forward by United Nations World Commission on Environment and Development (WCED) in 1987 in 'our common future'. Sustainable development is defined as 'meet the needs of the present without compromising the ability of future generations to meet their own needs' [9]. In 2002, the World Summit on Sustainable Development argued that sustainable development includes three aspects, which are social, environmental and economic sustainable development [10]. The United Nations Secretary's 2012 report emphasized that sustainable development offers chance for people to make production and consumption more sustainable and growth inclusive [11]. Lorek and Spangenberg [12] characterized sustainable development as 'living within the ecological limits and meeting the needs of everyone'.

Based on the concept of sustainable development, researchers conducted many studies about the industrial areas' sustainable development that is industrial sustainable development. To improve the sustainable development capacity of industry, government, enterprises and other stakeholders should take up some measures, such as implementing sustainable production and building industrial ecology and green industry [13,14]. The application of the concept of sustainable development drives industrial sector to a new industrialization road, whose characteristics are cleaner production, green technology, high-tech manufacture and remanufacture and less resources consumption and environmental pollution [15,16]. And in socio-economic development, lower inputs, higher efficiency and lower emissions are the characteristics of sustainable industrial development [17,18]. As a result, Nguyen and Ye [19] argued that 'sustainable industrial development is a new model of economic development that can achieve sustainable development and resolve the conflict between socio-economic development and environmental protection'.

2.2 Environmental practices in EIPs

Since the concept of EIP was proposed, a lot of researches on EIP have been conducted by academicians and practitioners. These studies mainly focused on industrial ecology theory (the theoretical basis of EIP) [20–22], industrial symbiosis (a core component of EIP) [23–25], EIP design [26,27] and EIP as regional development strategy [28,29]. Except these theory and strategy studies, there are some studies exploring the environmental practices of EIPs, which is the focus of this literature review.

From a personal perspective, environmental practice, also known as environmental behavior, includes actions such as responsible consumerism (e.g. choosing products that are recycled or environmental-friendly), resource conservation (e.g. reusing, energy conservation), use of nature (e.g. being outdoors), antitoxic (e.g. avoid use of toxic products in the garden/yard) and waste handling (e.g. recycling, composting, reduced littering) [30]. From an organizational perspective, environmental practice points to measures and actions (e.g. setting strict environmental standards, implementation of cleaner production, introducing green technology, improving managers' environmental awareness, increasing investment in environmental protection and pollution control) adopted by an organization according to their own characteristics and development strategy in the face of pressure from the government, the public and other stakeholders for environmental protection [31]. At present, EIPs' environmental practices have no uniform definition and division, and existing researches on the environmental practices of EIPs mainly focus on the four aspects, execution of environmental norms, construction of industrial symbiosis, popularity of eco-industrial knowledge and guidance to key enterprises.

Execution of environmental norms needs mutual efforts from stakeholders, especially EIP enterprise managers. The establishment, planning and operation of EIPs require enterprise managers to strictly implement environmental norms, such as energy conservation system, energy reduction system, waste recycling system and environmental information disclosure system, green technology support systems, including technologies for eliminating pollution, recycling waste and cleaner production, and other environmental-related systems, and gain the ISO14001 environmental management system certification and other environmental-related certification to reduce pollution emission and improve energy use efficiency [32–38].

Construction of industrial symbiosis is an important part for EIPs' implementation of industrial ecology and sustainable development. To build industrial symbiosis, EIPs should combine with related enterprises ecologically. For example, by means of cleaner production, waste exchange and recycling, the waste produced by an enterprise can become the raw material for another enterprise. Gradually, a closed-loop structure can be formed to minimize waste discharge and ultimately achieve pollution zero-emission. Some initiatives, such as by-product exchange, water and waste recycling, energy cascading, resource and information sharing, construction of eco-industrial networks and cooperation with stakeholders (suppliers, government agencies, communities, customers, etc.), are beneficial to build industrial symbiosis successfully [39–41].

Popularity of eco-industrial knowledge is very important to perfect EIPs' sustainable development. Some studies expressed that actions should be taken to enhance EIPs relevant personnel environmental awareness and knowledge to improve EIPs' ecological environment [42,43]. Deng [44] found that in an EIP, if enterprise leaders and members have a better understanding of ecology, the stability of EIPs will be improved.

Key enterprises' support for environmental sustainability principles and values is of importance to improve EIPs' sustainable development. Deng [44] stated that key enterprises can be helpful to build

EIPs' cohesiveness and stability, which is due to the environmental behaviors of key enterprises that have an positive influence on EIPs' other smaller enterprises. What's more, key enterprises usually have considerable effect in their EIPs because of their outstanding and central roles; they tend to stimulate EIPs' other enterprises to carry out environmental practices when they become pioneers and obtain experience, knowledge, economic benefit and social satisfaction from implementing environmental practices [45]. Thus, key enterprises in EIPs are guided to carry out environmental practices through making environmental protection-related policies and regulations and advocating the application of environmental management tools.

3 QUESTIONNAIRE DEVELOPMENT AND SAMPLES

3.1 Questionnaire development

Based on literature review and interviews with managers in Chinese EIP Administration Committees, this study developed 21 questions about environmental practices; these questions mainly focused on execution of environmental norms, construction of industrial symbiosis, popularity of eco-industrial knowledge and guidance of key species enterprises, which are shown in Table 1.

Sustainable development includes social, environmental and economic sustainable development [10]. Sustainable development of EIPs is based on applying sustainable development theory to the development of EIP; specifically, a park's development needs to achieve the common, sustainable and equitable development of critical systems, including the economy, resources and environment. Specifically, during the construction process of the park, the development process needs to maintain the harmonious and stable development of the economy, environment and society to reduce resource consumption and pollutants emissions and to achieve a balance between people and nature. Based
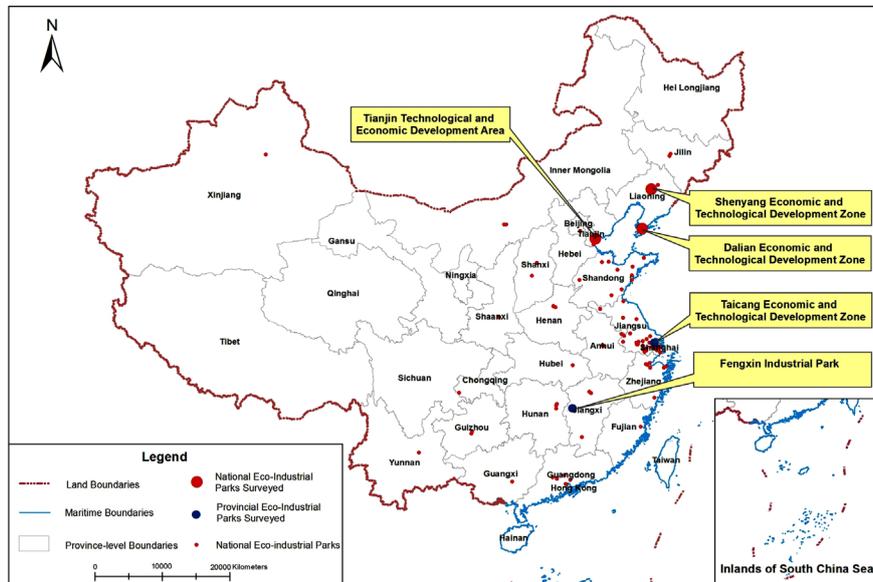

Figure 1: The geographical distribution of the national EIPs in China.

on the construction of EIPs and the sustainable development concept, 18 questions from the perspectives of economy, environment and society were selected, which are shown in Table 2.

3.2 Samples

The questionnaire is designed for EIPs' environmental practice and EIPs' sustainable development level. With the support of the National Natural Science Foundation of China, five national and provincial EIPs located in the eastern and central areas were selected to participate in the questionnaire survey; they are Tianjin Technological and Economic Development Area, Taicang Economic and Technological Development Zone, Fengxin Industrial Park, Dalian Economic and Technological Development Zone and Shenyang Economic and Technological Development Zone, which are shown in Fig. 1. Questionnaires were given to those EIPs' administration committees and the Economic and Information Technology Bureau, Development and Reform Bureau and Human Resources Social Security Bureau. The questionnaires were distributed from March to November 2011. A total of 308 questionnaires were distributed, 276 were received and 248 were valid, with the effective rate of 75.6%. The number of valid questionnaires meets the recommendation [46] that for the survey to be effective; the number of valid surveys should be at least five times the number of questions asked on the questionnaire.

4 METHODOLOGY AND DATA ANALYSIS

4.1 Methodology

In this article, factor analysis, one of the statistical analysis methods, was applied to deal with the data. Factor analysis is a statistical technique that extracts common factors from variable groups. It is an effective method to group those items containing more similar information into one variable so as to simplify analysis procedure by reducing the number of variables [47]. The main procedures of factor analysis are as follows. The first step is to judge whether variables are suitable for factor analysis or not. The criterion is KMO (Kaiser–Meyer–Olkin) value. When KMO value is above 0.8, the variables are suitable for factor analysis [48]. Second, according to the criteria of eigenvalue >1 and cumulative variance contribution rate more than 70% the main factors are extracted and the number of main factors is determined [49]. The third step is to conduct a reliability analysis to test the reliability of each main factor. The criterion is that Cronbach's α exceeds 0.70 [49].

4.2 Analysis of structural elements

4.2.1 Structural elements of EIP's environmental practice
To classify similar questions into groups, factor analysis was conducted for all 21 questions about environmental practices. The KMO (a statistic to judge whether variables are suitable for factor analysis or not) value is 0.967 (>0.8), which means that the variable is very suitable for factor analysis [50]. Considering factors with eigenvalues >1 and the cumulative variance contribution rate of the four main factors was 82.161% (>70%), the four main factors were extracted. Considering the meanings of the questions that were grouped into each main factor, the four main factors were named construction of industrial symbiosis, execution of environmental norms, guidance to key enterprises and popularity of eco-industrial knowledge, in decreasing order of their contribution. To further test the reliability of each main factor, a reliability analysis was conducted. The Cronbach α (a statistic to measure reliability) values are 0.922, 0.950, 0.964 and

Table 1: Factor analysis for environmental practices.

Variables	Questions	Factor				Contribution rate	KMO
		1	2	3	4		
Construction of industrial symbiosis	Park build the network platform which can help enterprises to exchange by-products and waste	0.606	0.353	0.434	0.161		
	Park supports the diversity of ecological industry chain	0.685	0.396	0.312	0.213		
	Water recycling between enterprises in the park	0.777	0.251	0.299	0.270		
	Energy cascade utilization between enterprises in the park	0.806	0.283	0.249	0.244	30.358%	0.967
	By- product exchange between enterprises in the park	0.793	0.198	0.299	0.216		
	Information sharing between enterprises in the park	0.788	0.283	0.232	0.306		
	Environmental cooperation between the park enterprises and outside vendors	0.769	0.305	0.261	0.339		
	Environmental cooperation between park enterprises and external customers	0.751	0.276	0.276	0.400		
Guidance to key enterprises	Park guides the keystone enterprise to develop cleaner production	0.316	0.666	0.373	0.260		
	Park encourages the keystone enterprises to obtain ISO14001 certification	0.317	0.684	0.409	0.329		
	Park promotes the keystone enterprises to develop and use renewable or clean energy resources	0.305	0.656	0.400	0.340	27.962%	
	Park encourages the keystone enterprises to improve energy efficiency and develop energy conservation	0.381	0.694	0.321	0.376		

Continued

Table 1: *Continued*

Variables	Questions	Factor				Contribution rate	KMO
		1	2	3	4		
Execution of environmental norms	Formulation and implementation of a management system which is suitable for the park's sustainable development	0.292	0.314	0.674	0.376		
	When making investments, the park sets limits for admission for enterprises and new industries based on their energy consumption, pollutant emissions and carbon emissions	0.325	0.333	0.697	0.355	15.156%	
	Park through regional ISO14001 environmental management system certification	0.313	0.274	0.627	0.454		
	Park carries out regional development environment impact assessments	0.405	0.302	0.712	0.162		
	Park strictly implements energy audits and controls energy use to eliminate waste of resources	0.478	0.383	0.549	0.277		
Popularity of eco-industrial knowledge	Promoting the eco-industrial and environmental knowledge in the scope of the park	0.325	0.316	0.370	0.703		
	Strengthening public awareness training of environmental protection and eco-industrial concept of cognitive	0.305	0.296	0.315	0.780	8.685%	
	Encouraging the park public to learn about environmental laws and regulations	0.318	0.329	0.279	0.721		
	Improving law enforcement capacity of law enforcement officers on the energy conservation and environmental protection	0.331	0.474	0.190	0.542		

Note: Convergence in seven iterations.

0.932; all of them exceed 0.70, which is the benchmark of reliability. Removing any one item will not significantly increase any of the four Cronbach α values, and in some cases, the Cronbach α value is reduced. Therefore, all of the questions in each main factor need to be retained [51]. According to the meaning of contribution rate in factor analysis and the main factors' contribution rate, it is reasonable to assume that the construction of industrial symbiosis factor contributes 30.358% of 82.161% to the environmental practices. Similarly, guidance to key enterprises contributes 27.962%, execution of environmental norms contributes 15.156% and popularity of eco-industrial knowledge contributes 8.685%. Table 1 shows the results of the factor analysis for environmental practices.

4.2.2 Structural elements of EIP's sustainable development level

Similarly, factor analysis was conducted to group the 18 questions of sustainable development levels. The factor analysis results (shown in Table 2) indicate that three main factors can be identified that have eigenvalues greater than 1. According to the meanings of the questions in each main factor, these main factors were named economic level, environmental level and social level. It is reasonable to assume that economic level contributes 33% of 75.5% to the EIP's sustainable development level. Similarly, environmental level contributes 21.5% and social level contributes 21%.

Following the analytic hierarchy process, EIP's sustainable development level (Level 1 indicator, y) can be subdivided into three sublevels: economic, environmental and social (Level 2 indicators, y_1, y_2 and y_3). The four main factors of environmental practices can be represented as Level 3 indicators (x_1, x_2, x_3 and x_4). The questions of environmental practices can be represented as Level 4 indicators (x_{ij}, $i = 1$–4, $j = 1$–8).

To calculate the impact of environmental practices on the sustainable development level of an EIP, the contribution of the economic, environmental and social level to the sustainable development level of an EIP first needs to be determined. Second, the impact of the four environmental practice factors on the three factors of sustainable development level needs to be determined.

To address the first question, the contribution rate of each level was used to calculate their weights. The weights c_i were obtained by normalizing the main factor contribution rates a_i:

$$c_i = a_i/(a_1 + a_2 + a_3) \tag{1}$$

In this equation, a_i is the contribution rate of main factor i and c_i is the weight of main factor i.

Using factor analysis, the contribution rates of three main factors are 33.044%, 21.516% and 20.956%, and the cumulative contribution rate is 75.516%. Therefore, from eqn (1), the contributions of the economic, environmental and social level to the sustainable development level are $c_1 = 0.428$, $c_2 = 0.285$, and $c_3 = 0.277$, respectively.

The relationship between sustainable development level and economic, environmental and social levels can be expressed as:

$$y = 0.428y_1 + 0.285y_2 + 0.277y_3 \tag{2}$$

4.3 The regression analysis between environmental practice and sustainable development level

A regression analysis was used to determine the contributions of the four factors of environmental practices on the three levels of sustainable development. The four factors of environmental practices were taken as independent variables, and the three factors of sustainable development, economic level, environmental level and social level were taken as dependent variables. The results are shown in Table 3.

Table 2: Factor analysis for sustainable development level.

Variables	Questions	Factor 1	Factor 2	Factor 3	Contribution rate a_i	KMO
Economic level	The park position on the economic scale of national industrial parks	0.747	0.227	0.296		0.945
	The market position of the park's leading industry	0.726	0.220	0.351		
	The impact of market changes on the overall development of the park	0.801	0.261	0.099		
	The impact of market changes on the leading industries in the park	0.829	0.282	0.169		
	The ability of the park to access foreign investment channels	0.769	0.257	0.319	33.044%	
	Park development efforts of strategy or policy	0.781	0.223	0.280		
	The attractiveness of the park for a growing business	0.745	0.312	0.359		
	The investment efforts of improving park existing industrial chain	0.679	0.297	0.412		
	The park staff satisfaction with wages	0.542	0.407	0.434		
Environmental level	The extent of saving water in the park	0.312	0.838	0.236		
	The extent of park energy recycling and reducing	0.345	0.832	0.230		
	The realized extent of by-product exchange between enterprises in the park	0.260	0.818	0.304	21.516%	
	The degree of park enterprise waste reduction	0.294	0.817	0.316		
Social level	The degree of public satisfaction of the park's employment stability and working conditions	0.451	0.327	0.543		
	The degree of public satisfaction with the park management	0.454	0.362	0.593		
	Awareness of the public to the concept of sustainable development	0.335	0.202	0.813	21.965%	
	The degree of park management emphasis on the concept of sustainable development	0.329	0.227	0.820		
	The park and the surrounding public's environmental awareness	0.149	0.311	0.759		

Note: Convergence in five iterations.

Table 3: The results of regression analysis between environmental practices and the three levels of sustainable development.

Dependent factor	Independent factor	Standardized coefficient	t	Sig.	Adjusted R^2	Tolerance	Durbin–Watson
Economic level, y_1	Constant		10.977	0.000			
	Construction of industrial symbiosis, x_1	0.010	0.108	0.914		0.656	
	Execution of environmental norms, x_2	0.602	6.437	0.000	0.476	0.660	1.821
	Guidance to key enterprises, x_3	0.524	6.021	0.002		0.532	
	Popularity of eco-industrial knowledge, x_4	0.128	2.110	0.036		0.615	
Environmental level, y_2	Constant		5.445	0.000			
	Construction of industrial symbiosis, x_1	0.609	4.793	0.006		0.773	
	Execution of environmental norms, x_2	0.531	7.048	0.000	0.715	0.570	1.986
	Guidance of key enterprises, x_3	0.326	3.960	0.001		0.720	
	Guidance to key enterprises, x_4	0.191	3.821	0.000		0.616	
Social level, y_3	Constant		6.079	0.000			
	Construction of industrial symbiosis, x_1	0.101	1.222	0.003		0.637	
	Execution of environmental norms, x_2	0.607	7.361	0.000	0.632	0.829	1.903
	Guidance to key enterprises, x_3	0.265	3.867	0.004		0.530	
	Popularity of eco-industrial knowledge, x_4	0.153	2.994	0.003		0.622	

The impact of the four factors of environmental practices, x_1, x_2, x_3 and x_4, on economic level y_1 is represented by b_{1j}, their impact on environmental level y_2 is represented by b_{2j} and their impact on social level y_3 is represented by b_{3j} (J = 1, 2, 3, 4). By normalizing the standardized coefficients in each regression analysis model, the values of b_{ij} (i = 1, 2, and 3 j = 1, 2, 3 and 4) can be determined. The relationship between the four factors of environmental practices and the three factors of sustainable development are described as follows:

$$y_1 = 0.070x_1 + 0.445x_2 + 0.387x_3 + 0.094x_4 \tag{3}$$

$$y_2 = 0.368x_1 + 0.320x_2 + 0.197x_3 + 0.115x_4 \tag{4}$$

$$y_3 = 0.09x_1 + 0.539x_2 + 0.235x_3 + 0.136x_4 \tag{5}$$

According to the eqns (3)–(5), the construction of industrial symbiosis contributes 7%, 36.8% and 9% to the economic, environmental and social levels of sustainable development, respectively. Similarly, the execution of environmental norms contributes 44.5%, 32% and 53.9%, respectively. Guidance to key enterprises contributes 38.7%, 19.7% and 23.5%, respectively. Popularity of eco-industrial knowledge contributes 9.4%, 11.5% and 13.6% to the three levels, respectively. It was also found that execution of environmental norms has the greatest impact on economic level and social level, and the construction of industrial symbiosis has the greatest impact on environmental level. Therefore, the contribution rates can be used to represent the weights of the Level 3 indicators (environmental practices) on the Level 2 indicators (the three levels of sustainable development).

4.4 The analysis of the impact of environmental practice on the sustainable development level

To calculate the effect of environmental practice (Level 3 indicators) on sustainable development (Level 1 indicator) in an EIP, the analytic hierarchy process was used to calculate the weights of Level 3 indicators on the Level 1 indicator. By using the weights c_i (eqn (1) of the three Level 2 indicators(economic level, environmental level and social level on the sustainable development) and the impact b_{ij} (impact of indicators Level 3 on indicators Level 2, as shown in eqns (3)–(5)), the weight w_j of Level 3 indicators (x_j) on the level indicator 1(y) can be calculated:

$$w_j = \sum_{i=1}^{3} b_{ij} \times c_i \tag{6}$$

According to eqn (6), the influence powers of the four factors of environmental practices on sustainable development level were calculated. The results of the calculations are as follows.
The impact of construction of industrial symbiosis on the sustainable development level is:
$$w_1 = 0.07 * 0.428 + 0.368 * 0.285 + 0.09 * 0.277 = 0.17$$

The impact of execution of environmental norms on the sustainable development level is:
$$w_2 = 0.445 * 0.428 + 0.320 * 0.285 + 0.539 * 0.277 = 0.43$$

The impact of guidance to key enterprises on the sustainable development level is:
$$w_3 = 0.387 * 0.728 + 0.197 * 0.285 + 0.235 * 0.277 = 0.29$$

The impact of popularity of eco-industrial knowledge on the sustainable development level is:

$$w_4 = 0.094*0.428 + 0.115*0.285 + 0.136*0.277 = 0.11$$

Among the four environmental practices of an EIP, the execution of environmental norms (43%) plays the greatest role in achieving the sustainable development of EIPs in China. Guidance to key enterprises (29%) has the second greatest effect on achieving sustainable development. Construction of industrial symbiosis is third (17%), and popularity of eco-industrial knowledge is fourth (11%).

5 RESULTS AND DISCUSSION

This paper used statistical analysis and analytic hierarchy process to identify the main factors of environmental practices that affect the sustainable development level of Chinese EIPs and to analyze the impact of different factors of environmental practices on the sustainable development level. The results are as follows.

First, the sustainable development of an EIP includes three factors: economic level, environmental level and social level. Economic level contributes the most to the sustainable development of an EIP, accounting for 42.8%. The second largest contributor, environmental level, contributes 28.5%. Social level contributes 27.7%.

Second, the environmental practice of an EIP includes four factors: construction of industrial symbiosis, execution of environmental norms, guidance to key enterprises and popularity of eco-industrial knowledge. The impact of these four factors on the three levels of sustainable development of an EIP was also analyzed and calculated in this article based on a regression analysis.

Third, using analytic hierarchy process, the impact of the four factors of environmental practice on sustainable development of an EIP was also analyzed. Execution of environmental norms has the greatest impact with a contribution rate of 43%. Guidance to key enterprises has the second greatest impact, with a contribution rate of 29%. Construction of industrial symbiosis is third, with a contribution rate of 17%. Popularity of eco-industrial knowledge is fourth, with a contribution rate of 11%.

To improve its sustainable development, an EIP in China first needs to issue specific environmental norms that are underpinned to its own characteristics under the frameworks of national and local requirement frameworks. For example, all of the enterprises in the EIP need to conduct cleaner production or energy auditing to ensure resource utility efficiency. An EIP also needs to consider identifying the key enterprises and providing them with guidance in environmental management and sustainable development, such as obtaining the certificate of environmental management system and trying to use renewable energy and resources. Industrial symbiosis, as a very important element in an EIP's sustainable development, is currently only the third contributor to the sustainable development of an EIP. That's possible because EIPs in China are in an early stage, and they are planning or just beginning to conduct industrial symbiosis. Therefore, the benefits from industrial symbiosis may be in the future. An EIP also needs to publicize knowledge on eco-industry and sustainable development by providing training or establishing clubs on waste minimization, for example. It is worth mentioning that EIPs in other countries may also face the same problems as those in China. Therefore, the results of this study might be worth of reference and application for governments and administration committees of EIPs.

6 CONCLUSIONS

The environmental practices of an EIP are critical to its sustainable development. This article first identifies three factors of sustainable development of an EIP: economic, environmental and social levels. Next, four types of environmental practices are identified using factor analysis; they are execution of environmental norms, guidance to key enterprises, construction of industrial symbiosis

and popularity of eco-industrial knowledge. Among those four practices, execution of environmental norms plays the most important role in promoting the sustainable development of an EIP. Guidance to key enterprises plays the second most important role. Construction of industrial symbiosis is the third most important practice, and popularity of eco-industrial knowledge is the fourth. To achieve sustainable development, an EIP needs to conduct these four types of environmental practices. First, an EIP needs to establish its own specific environmental norms to guide enterprises under the frameworks of national and local environmental norms. Second, the administration committee of an EIP needs to identify those key enterprises and help them conduct eco-industry. For example, the administration committee can help key enterprises conduct cleaner production, circular economy, green supply chain management and other practices to drive these key enterprises to operate sustainably. Third, an EIP should analyze product and waste flows throughout the entire EIP so that opportunities for by-product exchange and industrial symbiosis can be identified. Fourth, the administration committee of an EIP also needs to educate the public about eco-industry and sustainable development. For example, relevant training can be provided periodically to the enterprises and communities.

By extending the theory of planned behavior, this article has developed a framework and statistical results that reveal environmental practices that are needed to improve an EIP's sustainable development level. However, there are some limitations to the current study and further studies are needed. First, considering the difficulties of collecting data, only four cities were chosen for conducting surveys. More cities need to be included to broaden this study. Second, the results show that four types of environmental practices affect the sustainable development level of an EIP and that their impact can be calculated. Further studies need to be conducted to reveal how these four types of environmental practices affect the sustainable development of an EIP.

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