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Building the environmental performance index for industrial parks

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ABSTRACT

Measuring environmental protection activities is a matter of great concern over the years. In this study, the indicators for evaluating environmental protection activities in industrial parks was built according to the PDSIR model and based on Vietnam's legal framework, including 18 main subjects and 35 indicators. The environmental performance index of industrial park (EPIIP) was established based on the multi-criteria evaluation method and the analytic hierarchy process method. The results of the study indicated that the VSIP I industrial park reached 68.95 points (relatively good level). Moreover, the results also showed that VSIP I was one of the industrial parks practicing good performance to protect environmental problems.

Keywords: *Environmental performance index, indicators, industrial parks*

1. Introduction

Economic development is a top priority field of all countries in around the world and economic development associated with environmental protection is increasingly concerned. Sustainable development is indispensable in the context of increasing environmental pollution and climate change. In order to assess the current state of the

environment in the process of economic and social development, many environmental indicators and indexes have been released in recent years.

In 2005, the environmental sustainability index (ESI) was developed. The ESI is a measuring tool of the progress towards environmental sustainability of each country. The environmental sustainability index was implemented based on 5 main themes, 21 subjects and 76 indicators in related to natural resources, environment, ecology, institutions and society (Yale Center for Environmental Law and Policy & Center for International Earth Science Information Network, 2005). In 2006, Yale University and Columbia University in the United States published the Environmental Performance Index. The index enclosed 22 indicators representing 10 subject groups towards two main issue groups like environmental health and ecosystem vitality (Daniel Esty et al., 2006). Besides, a range of the studies conducted many environmental assessment indexes as India environmental sustainability index (Institute for Financial Management and Research, 2010), the fuzzy environmental quality index (Roveda. José Arnaldo Frutuoso, Maurício Tavares Mota, Sandra Regina Monteiro Masalskiene Roveda, Roberto Wagner Lourenço, & Antonio César Germano Martins, 2010), the environment quality index (U.S. Environmental Protection Agency, 2014). These researches were integrated environmental assessment tools for national or local levels that could not be used to assess environmental performance for industrial zones.

In Vietnam in July 2017, the whole country has 328 industrial parks (223 operating) established, accounting for 60-70% of the total FDI attraction of nation, contributing about 30% exports of the whole country and created job opportunities for over 2 million workers, contributing significantly to national budget.

In recent years, Vietnam has proclaimed many documents regulating environmental indicators supporting management policy. In 2013, the Prime Minister issued Decision No. 2157 /QD-TTg promulgating indicators for monitoring and evaluating local sustainable development in the 2013 - 2020 period (Prime Minister, 2013). In 2015, the Ministry of Natural Resources and Environment issued Circular No. 35/2015 /TT-BTNMT on environmental protection of economic zones, industrial parks and high-tech zones in order to strengthen the legal mechanism to protect the environment in the industrial park (Ministry of Natural Resources and Environment, 2015a). In order to have a legal corridors for environmental assessment and monitoring, the Ministry of Natural Resources and Environment has issued Circular No. 43/2015/TT-BTNMT on the national environmental indicator set and Circular No. 73/2017/TT-BTNMT on the system of natural statistical indicators of resources and environment sector (Ministry of Natural Resources and Environment, 2015b, 2017). However, these indicators has not been able to assess whether environmental protection activities in the industrial zone are good or

bad, moreover the system of indicators includes many indicators, making it difficult to communicate to the community. In 2018, the Ministry of Construction issued a circular on green growth urban construction targets (Ministry of Construction, 2018). In 2019, the Ministry of Natural Resources and Environment issued Decision No. 2782/QD-BTNMT on October 31 in 2019 promulgating the system of indicators for evaluating environmental protection activities of national center provinces and cities (Ministry of Natural Resources and Environment, 2019). Regarding industrial performance of the provinces and cities, there are currently no guidelines and regulations to evaluate the results of industrial environmental protection activities.

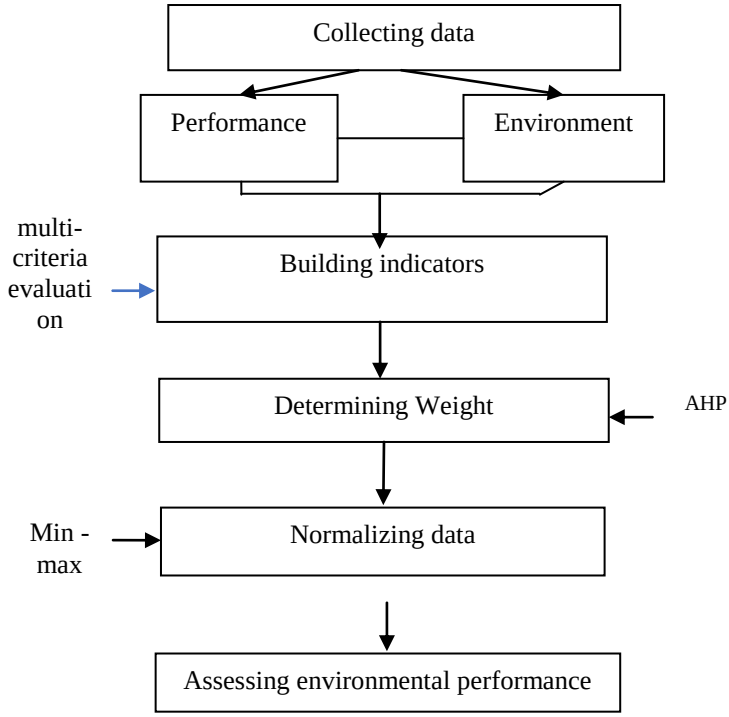

Figure 1. The progress of the study

From the above issues, the development of a indicator system and an index for evaluating the industrial environmental protection activities is very necessary. The study will contribute to the improvement of local environmental protection and support decision-making for environmental management agencies in concentrated industrial areas with the basis for evaluating and raking environmental protection of enterprises.

2. Materials and methods

***Materials*:** The research data was collected from the environmental monitoring reports in Industrial Park VSIP I in 2018 and conducted the field surveys.

Methods

The Analytic Hierarchy Process (AHP)

AHP is a semi-quantitative pairing comparison technique based on the method development of Saaty (1995) called hierarchy analysis. The weights for indicators and subjects based on the AHP method is the most optimal method that satisfy both objective and (consistency and statistics) and subjective (human opinions). The weight was determined by comparing to the significance of each indicator on a scale of from 1 to 9.

TABLE 1. Evaluation values of Saaty in paired comparisons

Comparative value of Saaty	Definition of judgment
1	Equal importance
3	Week dominance
5	Strong dominance
7	Demonstrated dominance
9	Absolute dominance
2, 4, 6, 8	Intermediate values

The evaluation results are expressed in the A matrix of the relationship of the indicators with each other

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{21}} & 1 & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix}$$

In order to demonstrate the assessment method, the study was used to 5 topics [drivers, pressures, state, impact, response] for an example. The matrix A of five theme was determined

$$A = \begin{bmatrix} 1 & 1/3 & 1/2 & 1/3 & 1/4 \\ 3 & 1 & 1/2 & 1/2 & 1/3 \\ 2 & 2 & 1 & 3 & 1/2 \\ 3 & 2 & 1/3 & 1 & 1/3 \\ 4 & 3 & 2 & 3 & 1 \end{bmatrix}$$

The geometric was calculated for each indicators in rows: $m_i = \prod_{i=1}^{n} a_{ij}$, $\overline{w_i} = \sqrt[n]{m_i}$

$= \begin{bmatrix} 0.43 \\ 0.76 \\ 1.43 \\ 0.92 \\ 2.35 \end{bmatrix}$, $w_i = \overline{w_i} \; / \sum_{i=1}^{n} \overline{w_i}$. The weighted vector was obtained as factors: W_{11}, W_{22}, W_{33},… W_{nn}. W = (0.07, 0.13, 0.24, 0.16, 0.40) = $\sum_{j=1}^{n} w_j = 1$. Then, the confidence of the matrix was implemented to check the consistency of the compared matrix among the indicators. The consistency of matrix A was calculated as follows:

After that, the total weight vector W for each row to get the vector B was computed to be obtained B weight matrix of the indicators: $\vec{B} = \sum_{j=1}^{n} a_{ij} = \begin{bmatrix} b_1 \\ b_2 \\ b_n \end{bmatrix} = \begin{bmatrix} 0.43 \\ 0.76 \\ 1.43 \\ 0.92 \\ 2.35 \end{bmatrix}$

and each element of vector B was devived by the corresponding element in vector W (W_{11}, W_{22}, W_{33},… W_{nn}) obtained the vector c: $\vec{c} = \begin{bmatrix} \frac{b_1}{w_1} \\ \frac{b_2}{w_2} \\ \frac{b_n}{w_n} \end{bmatrix} = \begin{bmatrix} 0.43/0.07 \\ 0.76/0.13 \\ 1.43/0.24 \\ 0.92/0.16 \\ 2.35/0.40 \end{bmatrix} = \begin{bmatrix} 5.38 \\ 5.27 \\ 5.41 \\ 5.39 \\ 5.08 \end{bmatrix}$, λ_{max} is the mean vector elements c: $\lambda_{max} = \frac{1}{n} \sum_{j=1}^{n} c_j = 5.31$. Then, the consistency index appraised by the formula: CI = $((max - n)/(n-1) = 0.08$. The consistency ratio CR = CI/RI = 0.08/1.12, if CR < 0,1 the pair comparison matrix A for the indicators was reasonable, otherwise we needed to re- evaluate the pair comparison matrix. In which, RI is taken according to the table 2:

TABLE 2. RI scale

N	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

CR = 0.08/1.12 = 0.07 <0.1. Therefore, the comparison matrix of the subjects in the PDSIR was reasonable and the weights were determined appropriately.

Standardized method

Data normalization could be done using the following formulas:

$$I = \frac{I_x - I_{min}}{I_{max} - I_{min}}$$

In which: I is the standardized indicator value, I_x is the indicator value, I_{min} is the minimum indicator value and I_{max} is the largest indicator value

Calculating the environmental performance sub-index

The environmental performance index was calculated step by step based on the indicator group. The sub-indicator was calculated using the following formula:

$$I_{Sub} = \frac{\sum_{i=1}^{n} I_i}{n}$$

In which, I_{Sub} is the sub-index of the indicator group, I_i is the standardized environmental protection activity index of the secondary directive i.

Combining the sub-index into the overall index of environmental protection performance

The EPIIP index was combined from the sub-indexes of the subjects according to the formula as $I_{LSX} = \sum_{j}^{n} w_j \, I_{Subj} \times 100$

I_{LSX} is the environment performance index EPIIP, W_j is the weight of indicator group jth, I_{Subj} is the sub-index of EPIIP j^{th}. The range level of EPIIP from 0 to 100.

TABLE 3. The proposed scale of the EPIIP

Scale	Level
1 - 20	Very bad
20 – 40	Bad
40 - 60	medium
60 - 80	Relatively good
80 -100	Good

3. Results

Building the indicator system for evaluating environmental performance in industrial parks

The indicator set was established based on the DPSIR model such as drivers - D (socio-economic development, the underlying cause of environmental changes); Pressure - P (direct sources of pollution and environmental degradation); S - the state of the

environment is affected; Impact - I (impact of environmental pollution on public health, socio-economic development and ecological environment activities); Response - R (environmental protection solutions) (Rainer Brüggemann & Ganapati P Patil, 2011). The indicator set used to evaluate environmental protection activities in the industrial park includes 18 subjects and 35 indicators, specifically as follows:

*TABLE 4.*The indicators of the EPIIP

Group subject	Subjects	Symbol	Indicators	Unit	Source
Driving forces	Industry Development	A01	Industrial zone fill rate	%	MONRE. 2015b
		A02	Rate of environmental industry	%	Offer
		A03	Proportion of tree cover in industrial park	%	Offer
		A04	Labor productivity of industrial zone	Million VND /person/ year	Prime Minister, 2013
Pressure	Climate Change	A05	The amount of greenhouse gas emissions	Tons /person/ year	MONRE, 2017
	Air environment	A06	The loading of PM10 per capita	Tons /person/year	MONRE, 2015b
		A07	The amount of TSP emission per capita	Tons /person/year	MONRE, 2015b
		A08	The amount of SO_2 per capita	Tons /person/year	MONRE, 2015b
		A09	Emission of NO per capita	Tons / person/year	MONRE, 2015b
	Water Environment	A10	Total amount of wastewater	m^3 /ha/Year	MONRE, 2015b
		A11	Emission of BOD_5 generated in an industrial park	Tons /year	MONRE, 2015b
		A12	The total emission N generated in industrial park	Tons / year	MONRE, 2015b
	Solid waste	A13	The amount of domestic solid waste released	Tons / ha / year	MONRE, 2015b
		A14	The amount of industrial solid waste generated	Tons / ha / year	MONRE, 2015b
		A15	The amount of hazardous waste emission	Tons / ha / year	MONRE, 2015b
	Environmental risk	A16	Environmental incidents	Number of cases	MONRE, 2017)
State	air environment	A17	Air quality index (AQI)		Offer
	water environment	A18	Water quality index (WQI)		Offer
	Soil environment	A19	Rate of degraded land area	%	MONRE, 2017
		A20	Proportion of contaminated land area	%	MONRE, 2017
	groundwater environment	A21	Groundwater quality index		Offer
Impact	Human health	A22	Proportion of employees suffering from occupational diseases related to	%	MONRE, 2015b

			environmental pollution in the enterprises		
		A23	Percentage of people with respiratory disease in polluted areas	%	MONRE, 2015b
	Environmental impact	A24	Rate of facilities causing environmental pollution were discovered during the year	%	MONRE, 2017
		A25	Proportion of budget expenditure for environmental protection activities	%	MONRE, 2017
	Environmental pollution management	A26	The rate of establishments causing environmental pollution is overcome	%	MONRE, 2015b
		A27	Proportion of business meet environmental standards or are certified with ISO 14001 or applied clean technology	%	MONRE, 2015b, 2017
Response	Wastewater control	A28	Rate of production, business and service establishments generating wastewater of more than $50m^3$/day have wastewater treatment systems to comply with national technical regulations	%	MONRE, 2015b
	Emission control	A29	Percentage of enterprises have air waste treatment systems	%	Offer
	Safety and health	A30	Percentage of establishments with fire protection certification	%	Offer
		A31	The number of environmental staff per 100 enterprises	People / enterprises	MONRE, 2017
	Clean energy	A32	Rate of renewable energy sources used	%	MONRE, 2015b
	Solid waste management	A33	Rate of collecting domestic solid waste	%	MONRE, 2015b
		A34	Rate of gathering industrial solid waste	%	MONRE, 2015b
		A35	Rate of hazardous waste is collected and treatment	%	MONRE, 2017

Determining weight of indicators and subjects for the EPIIP

TABLE 5.The weight of the subjects of the EPIIP

subject group	**Weight subject**	**Subjects**	**Weight subjects**
Driving	0.072	Industry Development	0.072
Pressure	0.129	Air environment	0.283
		Water Environment	***0.396***
		Solid waste	0.108
		Environmental risk	0.118

		Climate Change	0.094
State	0.243	Air environment	0.302
		Water environment	0.386
		Soil environment	0.175
		Underground water environment	0.137
Impact	0.157	human health	0.078
		Environmental impact	0.078
Response	0.399	Environmental pollution management	0.098
		Wastewater control	0.325
		Emission control	0.241
		Safety and health	0.105
		Clean energy	***0.059***
		Solid waste management	0.171

The results of Standardized indicators

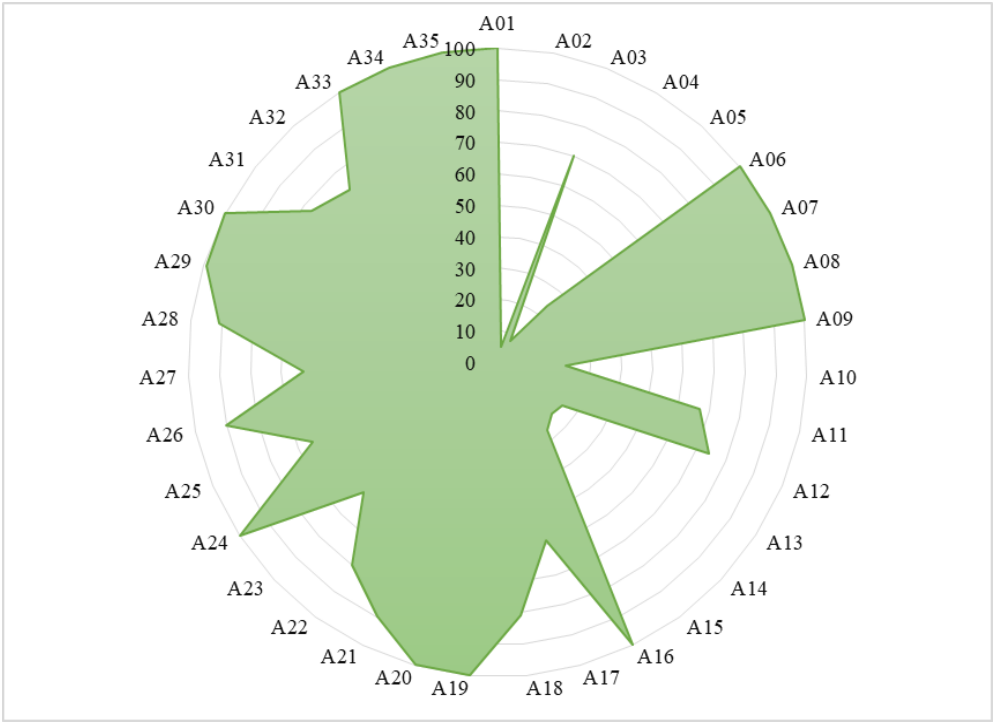

Figure 2. The standardized indicators of the EPIIP in VSIP I industrial park

The result of standardized indicator A24 (Rate of facilities causing serious environmental pollution) was 0%, showing that the environmental management was quite good in industrial zone VSIP I

Besides, the results also showed that the indicator A02 (Rate of environmental industry) is the lowest value of *0.05%*. It indicated that the environmental industry had not been invested and paid adequate attention in industrial park VSIP and had the lowest impact on environmental protection activities in there.

The range of indicators from A06 to A09, A19, and A20 (in the negative group) have the highest standardized values showing the influence of these indicators on environmental protection activities in industrial park VSIP.

The indicators from A33 toA35 (positive group) were the highest standardized scale, showing that the environmental management activities of industrial park VSIP I was a great influence on environmental protection activities.

The environmental performance index of industrial parks in the VSIP I, Binh Duong, Vietnam

Among the subject groups on environmental protection activities in the industrial areas, the topic of response were the highest level that indicated the environment played important role of the VSIP I Industrial Park to environmental management and protection issues. In fact, VSIP I Industrial Park was the earliest representative industry in Binh Duong province. With 100% of the land occupied, VSIP I has now attracted 231 projects with a total investment of about 3.2 billion USD. The project has created 95,000 jobs for workers and contributed to the industrialization, modernization and urbanization of Binh Duong province. Environmental management and pollution control in VSIP I have been carried out closely, in collaboration with the competent agencies and local environmental management agencies as well as the Central Government.

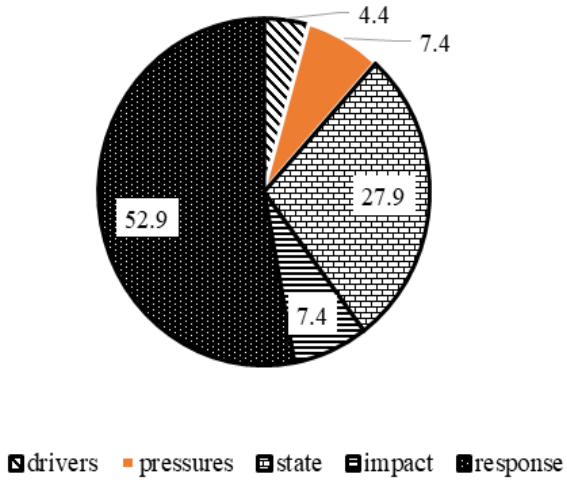

Figure 3. The sub-index of the EPIIP

Driving force subject group was little impact on environmental protection activities in industrial park. Thereby, it is shown that in order to have a better environment in the Industrial Park, the investment mechanisms, policies and business orientations in term of the environment were a greater influence than the promotion of the industrial zone's economic development.

4. Discussion

The environmental performance index of industrial park was an effective tool to assess the status of environmental protection activities in industrial zones. The indicator system was generally described by clear and easy-to-understand which improved environmental protection activities.

The environmental performance index of industrial park of VSIP I was 68,95 point (relatively good level) that pointed out the VSIP I carried out a range of measures to protect the environment. The environmental state and pollution control in VSIP I Industrial Park implemented a good practice.

Acknowledgments

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