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Research article

Assessment of Eco-industrial Park (EIP) Performance at the Preliminary Step in Vietnam

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Abstract

Vietnam has recently accelerated the process of converting traditional parks into eco-industrial parks (EIP), which is a foundational strategy for sustainable prosperity. The purpose of this investigation is to evaluate the efficiency of EIP operations at Ninh Binh, Danang, and Can Tho pilots. The full permutation polygon synthetic indicator method (FPPSI) was used to evaluate the initial effectiveness of the application of the EIP program with many different indicators. The results indicated a number of interesting outcomes. In particular, there were saving of 51% in LPG fuel, 67.1% in coal, and 78.1% in wastewater in Ninh Binh pilot compared to the overall figure for each category. At the Can Tho pilot project, it was found that savings of freshwater of 77%, an electricity cuts of over 66.8%, a COD decline of 77%, and cost benefits of 56%. Generally speaking, our economy needs to promote business engagement in the heavy industry sector in the near future. This will involve developing inventive symbiosis networks that run simultaneously.

Keywords

eco-industrial park;

industrial symbiosis;

efficiency;

Vietnam

1. Introduction

Alarmingly, two big world threats are resource insecurity and environmental degradation [1]. We are now more conscious of environmental concerns such as resource scarcity, iterative and incremental development, pollution, and climate change; problems that have devastating effects on ecosystems, human health, and socioeconomic development. Nevertheless, proposing unique and workable solutions for these challenges can be rewarding. The interrelationship between industrialization, urbanization, and the quality of the environment should be acknowledged as the foundation for long-term advancement and green growth. Recently, the concept of an eco-industrial park appears to adequately address these challenges [2]. It seems that EIP may be a solution to the many as yet unresolved concerns [3, 4]. In addition to being known as a small-scale circular economy, EIP shines a spotlight on energy and material efficiency [5].

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The first formal steps for the EU nations were symbolized by such a development model. Amazing accomplishments were made in the circular economy of wastes in 1990 in the Kalundborg Industrial Park in Denmark. By leveraging wastes as inputs for other businesses, these networks united several segments of the waste recycling value stream. Future expansion plans of zero-waste or sustainable development will benefit enormously from these early breakthroughs. A number of nations are aspiring towards this goal, and such challenges offer many economic possibilities [6]. Throughout that period, these phenomena flourished and were propagated throughout the advanced economies. Since then, the accomplishments have proven that developing nations can embrace and put into practice the concept of the EIP. In fact, the top economies that adopted this program can be listed: USA [7], Canada [8], Japan [9], South Korea [4], China [3], and European countries [10]. In recent years, the flourishing program has spread to developing countries through the support and guidelines of the United Nations Industrial Development Organization (UNIDO) under the joint global Resource Efficient and Cleaner Production (RECP) program and the United Nations Environment Programme (UNEP) [10]. Therefore, UNIDO has run EIP programs in various countries including Thailand, India, Morocco [11], and South Africa [12]. Especially, an EIP national project has been implemented in Vietnam, funded by the Global Environment Facility (GEF) and the State Secretariat for Economic Affairs of Switzerland (SECO) [13].

These days, emphasis is being placed on developing more effective methodological approaches in addition to the speedy implementation of the EIP concept. Many nations are now regularly analysing these approaches to promptly create better balanced strategies. Various mathematical models and ecological methodologies have been extensively applied to investigate and evaluate some of the blossoming EIP systems and their performances [14, 15]. However, the deployment of this strategy remains relatively new in emerging economies. Most developing countries do not employ any calculations to ascertain the efficiency of the EIP technique. Therefore, this study was aimed to assess the level of success that Vietnam's inaugural EIP program delivers, particularly as advanced countries are concentrating their efforts to invest in Vietnam’s priority sectors.

When it comes to resource, environmental, and savings metrics, knowledge of Vietnam's EIP performance has been limited by the analyses [10, 13]. These investigations have lacked consideration and assessment based on mathematical methods, resulting in unsystematic and disconnected outcomes [16, 17]. Before constructing a complete indicator system, it is critical to choose an adequate assessment approach. The mechanism of evaluation must aggregate all synthetic indicators of business for the firms in the industrial park into a more holistic package. One approach that can effectively achieve this is full permutation polygon synthetic indicator analysis (FPPSI). We decided to use the FPPSI approach, which can express the notion of the integrated system by modifying the traditional method to include quantitative indicators [18, 19]. As a part of the FPPSI methodology, a standardization of indicators is performed at the enterprise and industrial park levels.

Vietnam has had astounding development throughout the 2000s, with a GDP growth rate that is among the highest in the world at 7.9% [20]. This growth continued to accelerate and peaked at 6.8% in 2017. At the same time, this nation has grown to be one of the crucial nodes in the global and regional import-export chain [21]. Due to the country's overwhelming high fuel and material consumption, economic growth in Vietnam has been inevitable. All key resource kinds were considerably utilized between 2000 and 2017 according to the material consumption perspective. During this time, usage of metal ores, fossil fuels, non-metallic minerals, and biomass increased generally. Non-metallic minerals made up 528% of material expenditures. This sector scored significantly higher than metal ores (442.4%), fossil fuels (332.1%), and biomass (65%) (Figure 1a). Industrialization played a vital role in an upsurge of 348.9%.

At the same time, the transportation, agriculture/forestry, and service sectors each contributed 262%, 170%, and 132.3%, respectively, to the growth in energy consumption between 2000 and 2017. The bulk of the sectors' energy usage did t vary appreciably (Figure 1b). These findings imply that industrialization and modernization of infrastructure and manufacturing have advanced markedly in this nation [22]. Moreover, key business partners such as South Korea, Japan, Singapore, and others have been assisting and investing in Vietnam in order to develop building and industrial sectors. South Korea has continued to be the leading foreign investor in Vietnam with more than 59 billion USD in March 2018, followed by Japan (49.84 billion USD), Singapore (43.10 billion USD), and Taiwan ($30.94 billion). These numbers suggests that Vietnam's wealth will keep on increasing in the coming years [21].

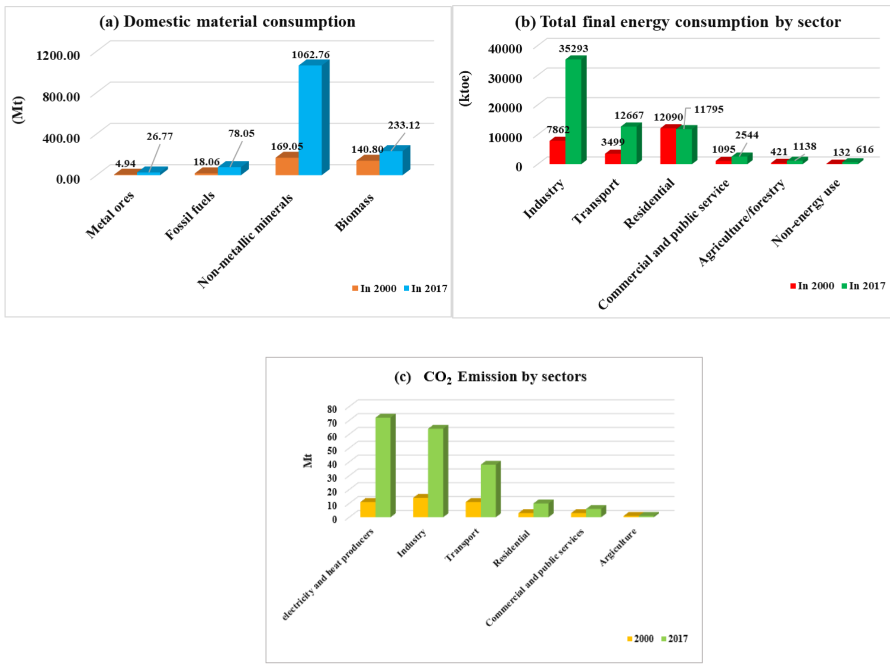

Figure 1. (a) Domestic material consumption (unit: Million tons); (b) Total final energy consumption by sector (unit: kilotonne of oil equivalent – ktoe); (c) CO_2 emissions by sector in Vietnam between 2000 and 2017

However, the effects of Vietnam's rapidly economic expansion have been harsh. As a result, greenhouse gas emissions have grown at a fast but steady rate in the main activities (Figure 1c). Between 2000 and 2017, industry, services, and transportation accounted for most of the emissions. As of 2015, there were around 43.6 million tons of solid trash generate per year. Furthermore, 22.1 million tons of that trash were residential trash. Industrial operations on a national scale provide 9.6 million tons. This showed a 10-16% annual rise [23]. Only 8-12% of solid waste volume was recycled [24]. Plastic, steel, paper, and metals were the most often recycled garbage, being responsible for an estimated 8.2% of total collected waste in 2014 [23].

Researchers have proposed several potential remedies in the context of agricultural waste. Examples include converting garbage into culinary inputs or organic waste into homegrown biogas. Economic and environmentally sustainable alternatives have recently been developed by diverting agricultural waste to other uses, for instance, making bio-fertilizers and furniture out of rice husk and sawdust [25, 26]. In general, garbage is still treated and repurposed on an ad hoc basis. Waste reuse and recycling are still underdeveloped, with insufficient synchronized management, assessment, and data. These flaws will result in significant environmental contamination in the long run.

The Vietnamese government needs to take definite initiatives in the face of threats to the environment, energy security, and resource depletion, and progress has been made since the Prime Minister authorized the Project "Implementing the Eco-Industrial Park Initiative to Develop Sustainable Industrial Zones in Vietnam" - decision 1526/Q-TTg on August 28, 2014. It strives to promote technological transition, hazardous waste reduction, and cleaner manufacture in this region [10, 27]. The Vietnam Ministry of Planning and Investment and UNIDO conferred and organized an EIP venture in three areas in 2014: (1) Ninh Binh province, which contains two industrial parks: Khanh Phu and Gian Khau, (2) Da Nang City, which has a special project prototype named Hoa Khanh industrial park, and (3) Can Tho province, which has two industrial parks: Tra Noc I and II.

This initiative drew in 72 firms from three areas to participate. However, 16 businesses dropped out and three companies refused to continue throughout implementation (note: further information can be seen in Figure 2).

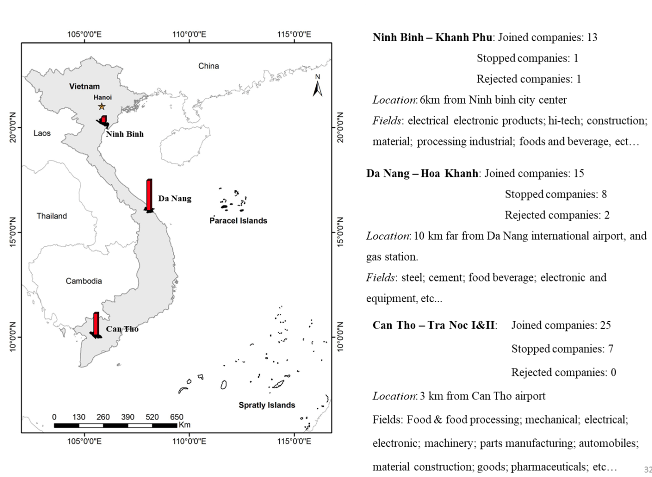

Figure 2. General information about EIPs in Vietnam

Several vital industries, including food and beverage, aquaculture, paper, construction materials, textiles, plastics, steel, chemicals, and fertilizers, were centralized. The Ninh Binh pilot project specializes in waste treatment, floating glass, knitwear, aluminum alloys, batteries, cement, asphalt emulsions, plastic bags, ball casting, jewelry, magnets, and fertilizers. The total preliminary investment for this region is 4101465 Euro. This investment was 1.44 times that of the Da Nang instance (2,857,108 Euro) and 1.41 times that of the Can Tho pilot project (2,905,877 Euro).

Paper, steel, ceramic, furniture, fishing rods, cloth, oil-fuel filters, and refrigeration are some of the main areas of manufacturing in the Da Nang - Hoa Khanh industrial zone. In contrast, the Can Tho - Tra Noc I and Tra Noc II EIPs have developed their food industry, with production of seafood, and beverages including coffee and milk. Tra Noc I and Tra Noc II both also manufacture steel, craft paper, gloves, leather, fertilizer, biological pesticides and gas.

Aggregated industrial activity in an industrial zone provides the opportunity to construct industrial symbiosis networks for a variety of by-products and wastes. Yet, it remains difficult for specialists and managers to generate and apply the concepts related to symbiotic firms.

According to this research, the study may well be a pioneer one in the assessment of EIPs in Vietnam. This study aims to standardize the values of several indicators that can be described at the enterprise and industrial park levels and to find out the most successful EIP pilot project.

2. Materials and Methods

2.1 Data

The International Energy Agency (IEA) [28], World Bank indices [15, 29, 30], and many official Vietnamese papers were used to compile socioeconomic statistics about Vietnam [25, 31-34]. Economic, environmental, and social variables were gathered to create the EIP database. They were the primary factors used to analyze and assess EIP performance. The final paper "Eco-Industrial Park Initiative for Sustainable Industrial Zones in Vietnam: Industrial Symbiosis Feasibility Study and Implementation - Version: 16^{th} May 2019" shows the detailed results [35]. Moreover, various assumptions were formulated:

(1) In this study, the impact of excitability, technological development, and wealth were examined (economic growth). Past, continuing policies and future plans do not take into account driving variables that have no influence on the study's conclusions. Concurrently, the profit hypothesis remains constant regardless of the factors indicated above.

(2) Environmental savings and energy savings are advantages. The study's input indicator is investment cost (unit: Euro). Output indicators include the following variables: (a) materials (ton), (b) electricity (kWh), (c) water (m^3), (d) fuel LPG (ton), (e) chemicals (ton), (f) coal (ton), (g) wood (ton), and (n) money savings (Euro). The following environmental advantages as indicated as reductions that are identified in this study are: (i) polychlorinated dibenzo (p) dioxins and furan PCDD/F (μg), (j) COD (kg), (k) solid waste (ton), and (m) wastewater (m^3).

2.2 A full permutation polygon synthetic indicator method (FPPSI)

A number of previous research studies adopted the FPPSI technique to assess economic, social, and environmental performance. Over two decades, urbanization in China's Jining city was analyzed using 52 metrics. They included the main aspects of economic growth, ecosystem, infrastructure, environment, society, and welfare. Many of those studies highlighted the benefits of the FPPSI approach [15]. In one study, the technique was used to better understand agricultural standardization in peach orchard ecosystems using green indicators such as atmospheric environment, irrigation, soil, seedling quality, and the influences of living conditions on peach orchard growth [36]. Likewise, the technique was used to investigate urban government effectiveness in Sri Lanka [37]. Furthermore, 13 limited indicators out of 33 deemed significant environmental sustainability indices in the urban industry from Chinese cities were studied between 2005 and 2017.

Deng's 2020 study demonstrated that this approach was extensively employed in numerous sectors, including data normalization and index aggregation [38]. The usual scale was replaced by a synthetic scale ranging from -1 to 1 and a multidimensional method was used to analyze embedded system principles for all indicators [19]. The FPPSI approach's strength is that it can be used to assess all values above and below a certain threshold, which avoids the requirement for subjective discretion evaluation. This is because the approach does not need adjustment of the synaptic weights [39].

A polygon with n-sides represents n-indicators with an upper limit of all indicators as the radius and connecting lines of indicator values. Its forms have an irregular center. Likewise, a total of $n \times (n-1)/2$ distinct irregular center n-gons may be formed using the n indicators [19, 39]. The normalization process is expressed as a function F(t), and it takes a value between [-1, 1] [39, 40].

$$F(t) = \frac{a(t+b)}{t+c}\ (a \neq 0; t \geq 0) \tag{1}$$

F(t) needs to satisfy F(L) = -1; F(T) = 0; and F(U) = 1, in which L is the lower limit. Similarly, U is the upper limit of the indicator t, and T is the threshold of the indicator t. Based on the three conditions above, we figure out that the specific set of numbers (a; b; c) are:

$$a = \frac{U-L}{U+L-2T};\ b = -T;\ \text{and}\ c = \frac{UT+LT-2UL}{U+L-2T}$$

When F(t) can be rewritten by the equation below:

$$F(t) = \frac{(U-L)(t-T)}{(U+L-2T)t+UT+LT-2UL}\ \text{with}\ t \in [L, U] \tag{2}$$

Where, $t \in (L, U)$
When $t \in (T, U)$, $F''(t)>0$
When $t \in (L, T)$, $F''(t)<0$
At the i-th indicator is:

$$S_i = \frac{(U_i - L_i)(t_i - T_i)}{(U_i + L_i - 2T_i)t_i + U_i T_i + L_i T_i - 2U_i L_i} \tag{3}$$

S_i presents the standardized indicator value
U_i denotes the upper value of the existing value
L_i indicates the lower value of the existing value
t_i is the value of the indicator
T_i performs the target value of the indicator
The full polygon n-sides are described in equation (4) below:

$$S = \frac{1}{2n(n-1)} = \sum_{i=1}^{n} \sum_{k=1}^{n} [(Si+1)][(Sk+1)] \qquad i \neq k \tag{4}$$

S is the value of the synthetic indicator.
S_i is the minimum value of the standardized value
S_j is the maximum value of the standardized value
N is several indicators.

Where the center point is represented by S_i = -1. The distance from the center point to the corresponding standardized indicator is known as the radius. An inner polygon between the outer polygon and the center of the polygon represents the threshold values of the dices, where S_i = 0 when t_i = T.

Besides, a quantitative description of the performance level is concededly classified under four thresholds (Table 1).

Table 1. Classification of indicator levels

Range of values	Level
> 0.75	Excellent
0.5 – 0.75	Good
0.25 – 0.5	General
< 0.25	Poor

3. Results and Discussion

3.1 The full permutation polygon synthetic indicator for each region

The heatmaps display 13 criteria for each EIP pilot project (Tables 2, 3, and 4), and indicate EIP performance at each enterprise level. Overall, for each pilot, electricity, water, CO2, PCDD/F, COD, wastewater, and money savings are more active and dynamic than the other indicators (material, LPG, chemical, coal, wood, and solid waste). Thirteen enterprises have an officially unified EIP program as part of the Ninh Binh pilot project (Table 2). The Duong Giang Co. Ltd – Trang, a floating glass plant, is plainly seen. It has produced exceptional results in terms of resource conservation (particularly over 3,700,000 kWh electricity/year) and emission reduction (12473 ton CO2/year; 2511.6 PCDD/F/year). Other firms have presented badly, with most of the color scales having lower than zero limitations. The data shows that the varying achievements among these companies were significantly different.

Most of the paper and textile industries have recorded material-saving results at the Da Nang pilot project (Table 3). The Chau Architecture and Trading Co.Ltd - Tan Long Paper factories achieved 7 indices with the highest value out of the total 13 indicators, followed by Daiwa Vietnam Co.Ltd and Da Nang Dairy Factories. Meanwhile, the Vinamilk firm has an upper bound value for several vital benchmarks (material; water; wood; CO2; PCDD/F; COD; and wastewater indicators). Nonetheless, chemical savings and coal reductions appear to be insignificant. This proves that fossil fuels continue to play an important role in practically all firms in this sector. Chemical mitigation strategies in industrial industries have yet to produce realistic solutions. This implies that the characteristics of each industry make it impossible to design symbiotic linkages in industry.

Although diverse success stories have been seen among the 25 investigated enterprises in the Can Tho pilot project (Table 4), normal wastes (wastewater), resources (water supply), and energy (electricity) play a significant part in the entire milestone. Some businesses have produced stunning performances. For example, food and beverage companies (Saigon-Western Beer JSC-Saigon beer Can Tho factory; Hanoi-Can Tho seafood JSC; Vietnam dairy products JSC Vinamilk-Can Tho dairy factory; CP Vietnam corporation; and Co Chien Co, Ltd), and a few steel - equipment companies (Tay Do steel Co. Ltd), produced high levels of performance (Table 4). Thus, across all analyzed regions, nonrenewable and toxic and hazardous cutbacks (LPG, chemicals, PCDD/F, hazardous wastes) showed inadequate reductions.

3.2 Full permutation polygon synthetic indicator for comparison in the three-pilot projects

Table 5 depicts a performance comparison at the park level using the FPPSI technique under the total value for each indicator in a given industrial park. It should be noted that divisions of substance and pollutant decline at the Ninh Binh - Khanh Phu and Gian Khau industrial parks score poorly for

Table 2. The heatmap of EIP indicators in Ninh Binh pilot at the enterprise level

(a)	Ninh Binh pilot	a	b	c	d	e	f	g	h	i	j	k	m	n
1	Thanh Nam Construction and Commerce Co., Ltd	-1	-0.99	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1
2	Eni-Florence Vietnam Co., Ltd	-1	0.25	0.13	1	-1	-1	0	-0.28	-0.65	0.05	-1	1	0
3	Duong Giang Co., Ltd - Trang An floating glass factory	1	1	-1	-1	-1	1	0	1	1	-1	1	-1	1
4	Chia Chen Co., Ltd	-1	-0.58	1	-1	1	-1	0	-0.85	-0.92	1	-1	-0.86	-0.73
5	Ninh binh electric Mechanical Co., Ltd	0.82	-0.86	-0.67	-1	-1	-1	0	-0.95	-0.98	-0.65	-1	-1	-0.85
6	Cement equipment Co., Ltd	-1	-0.76	-1	-1	-1	-1	0	-0.92	-0.96	-1	-1	-1	-0.91
7	Changxin Vietnam Co., Ltd	-1	-0.28	-1	-1	-1	0.18	0	0.07	-1	-1	-1	-1	0.01
8	Hoang Phat Vissia Group Co., Ltd	-1	-0.20	-1	-1	-1	-1	0	-0.67	-0.83	-1	-1	-1	-0.62
9	HAS Fashion Co., Ltd	-1	-0.94	0.28	-1	-1	-1	0	-0.98	-0.99	0.19	-1	-0.98	-0.96
10	Bachchambard Co., Ltd	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1
11	Dong duong Magnetic Material Co., Ltd	-1	-0.91	-0.79	-1	-1	-0.94	0	-0.93	-0.92	-0.77	-1	0.18	-0.93
12	Great Global International co., Ltd	-1	-0.45	0.42	-1	-1	-0.26	1	-0.43	0.35	0.33	-1	-0.97	-0.20
13	Vietnam K's International Polybags JSC.	-1	-0.70	-1	-1	-1	-1	0	-0.89	-0.97	-1	-1	-1	-0.95

Table 3. The heatmap of EIP indicators in Da Nang pilot at the enterprise level

(b)	Da Nang pilot	a	b	c	d	e	f	g	h	i	j	k	m	n
1	America Vietnam steel Corporation	-1	-0.23	0	-1	0	0	-1	-0.23	-0.71	0.07	-1	0.07	-0.27
2	Trung A Manufracturing and Trading Co., Ltd	-0.89	-0.54	-1	-1	0	0	-1	-0.54	-0.84	-1	-1	-1	-0.65
3	A Chau Architecture and Trading Co., Ltd - Tan Long Paper factory	1	1	-0.34	-1	0	0	1	1	1	-0.33	1	-0.40	1
4	Nguyen Phuc paper Co., Ltd	0.88	-0.91	-0.98	-1	0	0	0.39	-0.90	0.22	-0.98	-1	-0.98	-0.71
5	19-5 Garment enterprise-Ministry of public security	-1	-0.71	-1	-1	0	0	-1	-0.71	-0.92	-1	-1	-1	-0.83
6	DIC Danang Investment & Trading JSC.	0.64	-0.93	-1	-1	0	0	-1	-0.93	-0.98	-1	-1	-1	-0.58
7	Vinafor Danang JSC	-1	0.20	-0.50	-1	0	0	-1	0.20	-0.45	-0.47	-1	-0.46	-0.06
8	Viet Lang Forest Product Co., Ltd (FDI)	-1	-0.72	-1	-1	0	0	-1	-0.72	-0.92	-1	-1	-1	-0.84
9	Daiwa Vietnam Co., Ltd	-1	0.52	0.88	1	0	0	-1	0.52	-0.18	0.96	-1	0.96	0.61
10	Danang printing & Service JSC	0.97	-0.90	-0.98	-1	0	0	-1	-0.89	-0.98	-0.98	-1	-0.98	-0.91
11	Ba Loc Adhesive and Abrasive Cloth Co., Ltd	-1	-0.63	-0.80	-1	0	0	-1	-0.63	-0.88	-0.75	-1	-0.78	-0.74
12	SEA refrigeration Electrical Engineering (SEAREE)	-1	-0.84	-0.84	-1	0	0	-1	-0.84	-0.96	-0.82	-1	-0.82	-0.87
13	Danang Dairy Factory - Vinamilk	-1	0	1	-1	0	0	-1	-0.10	-0.63	1	-1	1	0.39
14	Secoin Danang JSC	-1	-1	-1	-1	0	0	-1	-1	-1	-1	-1	-1	-1
15	NBB Industry holding company	0.06	-0.88	-1	-1	0	0	-1	-0.88	-0.96	-1	-1	-1	-0.03

Table 4. The heatmap of EIP indicators in Can Tho pilot at the enterprise level

(c)	Can Tho pilot	a	b	c	d	e	f	g	h	i	j	k	m	n
1	Quang Minh Seafood Co., Ltd	-1	-1	-1	-1	-1	0	-1	0.22	0.05	-0.14	-1	-0.33	0.29
2	Nam Tien JSC	-1	-1	-1	-1	-1	0	-1	-0.70	-0.73	-1	-1	-1	-0.78
3	Nam Hai SEAfood processing Export Co., Ltd	-1	0.46	-0.9	1	-1	0	-1	0.34	0.11	-0.83	-1	-0.88	0.29
4	Thanh The Seafood Co., Ltd	-1	0.08	0.15	-1	-1	0	-1	-0.08	-0.20	-1	-1	0.27	-0.03
5	BIO Vietnam Co., Ltd	-1	-0.89	-0.71	-1	1	0	-1	-0.91	-0.94	-0.61	-1	-0.72	-0.86
6	Mekong river Orchards JSC	-1	-0.96	-0.96	-1	-1	0	-1	-1	-1	-0.94	-1	-0.96	-1
7	CP Vietnam Corporation	-1	0.60	-0.45	-1	-1	0	1	1	1	-0.18	-1	-1	0.49
8	Tri-Viet International Co., Ltd	-1	-0.59	-0.78	-1	-1	0	-1	-0.69	-0.70	-0.63	-1	-0.74	-0.73
9	Tay Do Steel Co., Ltd	-1	0.73	-0.91	-1	-1	0	-1	0.94	0.31	-0.87	1	-0.91	1
10	Nam Hung Phat packaging Manufacturing and Trading LLC	-1	-0.92	-0.97	-1	-1	0	-1	-0.96	-0.55	-0.96	-1	-0.97	-0.95
11	Co Chien Co., Ltd	-1	0.48	0.59	-1	-1	0	-1	0.30	0.11	-0.99	-1	0.58	0.42
12	Saigon-Western Beer JSC - Saigon Can Tho Beer factory	-1	1	0.72	-1	-1	0	-1	0.85	0.52	-0.99	-1	0.71	0.82
13	Nguyet Trang manufacturing and Trading Co., Ltd	-1	-0.95	-0.82	-1	-1	0	-1	-0.99	-1	-0.75	-1	-0.83	-0.96
14	Mekong Fisheries JSC	-1	0.85	-1	-1	-1	0	-1	0.69	0.40	-1	-1	-1	0.49
15	KWONG lung Mekong 2 Co., Ltd	-1	0.47	-0.39	-1	-1	0	-1	0.29	0.11	-0.22	-1	-0.40	0.16
16	Tam Phuong Nam Seafood JSC	-1	-0.43	-0.27	-1	-1	0	-1	-0.55	-0.59	-0.09	-1	-0.28	-0.51
17	Can Tho Mechical electrical machinery JSC - MITAGAS factory	-1	-0.86	-1	-1	-1	0	-1	-0.92	-0.92	-1	-1	-1	-0.94
18	Hung Phuc ONE Member Co., Ltd	1	-0.28	-1	-1	-1	0	-1	-0.41	-0.47	-1	-1	-1	-0.46
19	Huu Sang Co., Ltd	-1	-0.95	-0.97	-1	-1	0	-1	-0.99	-0.99	-0.95	-1	-0.97	-1
20	Can Tho ferilizer & Chemical JSC	-1	-0.22	-0.66	-1	-1	0	-1	-0.36	-0.42	-0.54	-1	-0.67	-0.45
21	Can Tho ferilizer & Chemical JSC - Co Bay Animal Feed factory	-1	-0.83	-0.98	-1	-1	0	-1	-0.89	-0.90	-0.97	-1	-0.98	-0.92
22	Vietnam dairy products JSC (VINAMILK) - Can Tho Dairy factory	-1	0.20	0.99	-1	-1	0	-1	0.03	-0.10	0.99	-1	0.99	0.63
23	Hanoi - Cantho Seafood JSC	-1	0.14	1	-1	-1	0	-1	-0.03	-0.15	1	-1	1	0.61
24	Can Tho import export fishery limited (CAFISH)	-1	-0.39	-1	-1	-1	0	-1	-0.52	-0.56	-1	-1	-1	-0.63
25	Pataya Vietnam food industries Co., Ltd	-1	-0.69	0.18	-1	-1	0	-1	-0.77	-0.78	0.35	-1	0.17	-0.50

Note: a-material indicator (ton); similarly, b-electricity (kWh); c-water (m^3), d-fuel LPG (ton); e-chemicals (ton); f-coal (ton); g-wood (ton); and n-saving money (Euro) indicators. Environmental benefits are presented by h-CO_2 (ton); i-polychlorinated dibenzo (p) dioxins and furan PCDD/F (µg); j-COD (kg); k-solid waste (ton); and m-wastewater (m^3).

Table 5. The heat map of the full permutation polygon synthetic indicator analysis to compare the three-pilot project performances (at park level)

Park level	a	b	c	d	e	f	g	h	i	j	k	m	n
Ninh Binh	-1	-1	-1	1	1	1	-1	0.58	1	-1	-1	1	-0.713
Da Nang	1	-0.940	-0.383	-1	-1	-0.012	1	-1	-1	-0.36	1	-0.53	-1
Can Tho	-0.86	1	1	0.56	0.20	-1	-0.27	1	0.0039	1	-0.51	-1	1

outcome is favorable in comparison to the areas of LPG, chemicals, coal, PCDD/F, and wastewater reduction. In terms of other indices, LPG scores 51% in total performance, saving more than 67% in total chemical savings across all pilot projects. Even so, the overall PCDD/F accomplishment is 39.6%. Finally, 78.2% for the wastewater metrics indicates a good performance.

The Da Nang - Hoa Khanh industrial park has two unique rankings (bad - good) (Table 1). The remarkable result for material savings accounts for 87.3% of total material savings in the EIP program. Following that, large quantities for wood saving and solid waste minimization contribute roughly 51.2% and 69.9% of their overall values, respectively (Figure 3). Chemical saving performance does not show any breakthroughs. Other signs might be a third or minority value.

Can Tho province - Tra Noc I and Tra Noc II: The EIP presentation in this area was attained from general to excellent level. For example, the maximum energy savings in the three pilot projects is 66.9% while Ninh Binh and Da Nang reported comparable figures (about 16%). Saving of tap water also exceeds 77.1% of the overall worth. It is ahead of COD results with 77.4%. Upwards of half of all saving costs are accounted for. Carbon emission decrease is recognized as a noteworthy indication for greenhouse gases. This indicator is responsible for 37.4%, 22.9%, and 39.7% of the total in Ninh Binh, Da Nang, and Can Tho, respectively (Figure 3). Other indicators with values more than the minimal value include material, LPG, chemicals, wood, PCDD/F, and solid waste (-1). Despite the fact that some obtained general and greater levels (Table 5). It implies that the majority of Can Tho's partnering firms made a considerable response to pollution abatement and resource conservation.

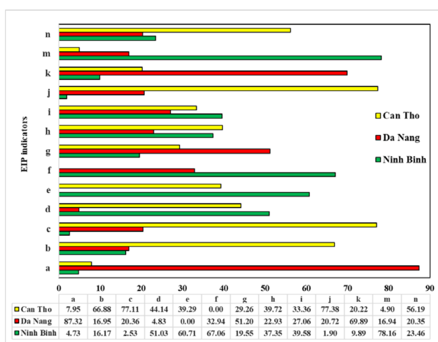

Figure 3. Comparison of the performance of each industrial park on the total at each indicator

3.3 Policies for supporting the EIP program in Vietnam

Vietnam made a prompt move towards sustainable development and resource conservation in the early 2000s. A few other key decrees, rules, and programs have been issued and executed to boost the economy and bring it into line with global sustainable development trends including: Agenda 21 Sustainable Development (2004) [41]; Energy Efficiency (2006) [42]; Green industry (2008) [43]; Five-year Socio-Economic Development Plans (2006-2010) and (2011-2015), and Towards (2016-202) [31] (Figure 4). These and other provisions, strategies, and initiatives were viewed as stepping stones in Vietnam's study and development of EIPs. Industrial park development planning and management; cleaner production and resource efficiency (2009); National action plan on green growth - Renewable energy development (2014); and environmental management and climate change mitigation were some ambitious measures (2011-2015) [44, 45].

Vietnam has been developing a form of EIP, standard assessment, master planning, and policy creation since 2014. It is the formal start of the EIPs program across the country. Vietnam has built its framework that is based on the worldwide EIP framework through the adoption of Decree 29 (planning IPs) and Decree 164 (Managing IPs). The structure has been constructed to fit with the Vietnamese scenario. The initiative invites Vietnamese firms to join willingly in the program. In addition, they will get awards, leases, grants, and other financial incentives, along with some preferential policies (EIP Vietnam_National Technical Guideline_ 22-03-2018). Resource Efficient and Cleaner Production (RECP) and Eco-industrial Parks (EIPs) targets have been implemented in parallel with the three levels (Bronze, Silver, and Gold) [10, 46].

Furthermore, the framework is quite adaptable in terms of evaluation and monitoring for each level, which is another hallmark of Vietnam's EIPs program. Referring to successful EIPs initiatives in typical nations such as Korea, however, reveals that Vietnam is still uninterested in utilizing numerous criteria. This is the case at the level of EIP and the local community. Moreover, Vietnam's EIP framework lacks motivational indicators that are used in Korea's EIPs which include Business Planning, Business Performance, and so on [47]. The inclusion of such indicators will assist in attracting outside investment and spark initiative in profitable business setup and industrial symbiosis network partnership in Vietnam's EIPs.

As such, information should be shared with all partners on a yearly basis and should result in better outcomes. Oversight results should progressively employ ecological technologies such as life cycle assessment (LCA), material flow analysis (MFA), data envelopment analysis (DEA), and so on, so that managers and experts can immediately control and address problems to reduce risks and waste inputs.

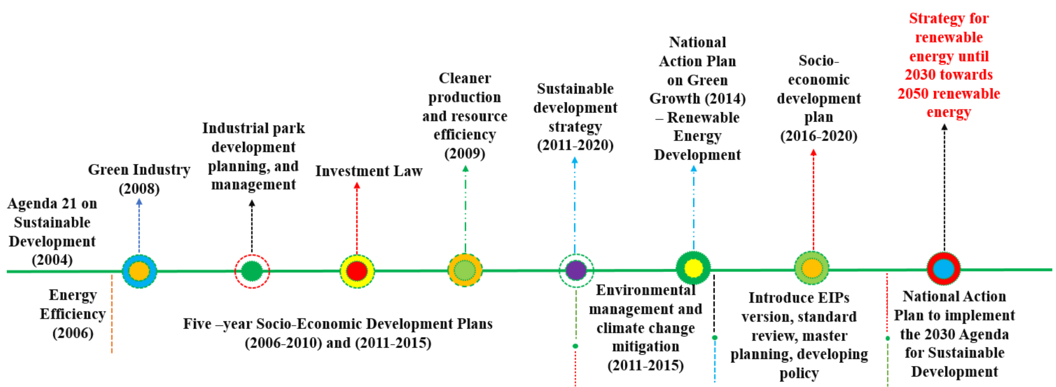

Figure 4. Vietnamese legislative and policy frameworks with enforcement suggestions and industrial development strategies during 1990-2017

3.4 Discussion

According to the research findings, the initial use of the EIP program in Vietnam did not provide any big progress compared to other initiatives such as cleaner production. For more effective industrial transformation, researchers should refer to worldwide EIP programs and also the conditions of Vietnam's industrial zones. However, the author identified several opportunities for environmentally sound production in three industrial parks, some of which are being developed.

(1) Wood chips, and sawdust can be used by the paper industry, or as fillers for leather shoes and furnishings, or can be used by manufacturing companies that use wood as an input material.

(2) Organic waste is prevalent in the food, beverage, agricultural goods, and seafood processing sectors. It can be a plentiful source of material for the bio-fertilizer sector.

(3) In particular, the next EIP programs should focus on building more industrial symbiosis networks for heavy industries to support hazardous waste treatment. For example, waste from iron and steel manufacturing, plating, glass, coal and sludge from various sectors ~~such as~~ can be used for the creation of refractory bricks and cement.

(4) A new direction in the pursuit of low-cost activated carbon and adsorbents for agro-waste environmental cleanup. This is also a new source of cash for the agricultural and agro-processing sectors.

(5) For sectors that generate a lot of heat, such as metallurgy, ceramics, and burnt brick manufacturing sectors, the heat can be used to dry food. In the winter, it also provides heat to industrial and residential regions.

(6) Wastewater discharged into the environment satisfies the necessary parameters after treatment. This water can be used as a water source for certain applications in industrial parks and neighboring residential areas. Furthermore, another way to make use of this waste water is to use it to produce concrete.

(7) Roofs in industrial parks can be better utilized in the solar power systems. These systems can contribute to the reduction of national grid load and the cost of related products and services.

(8) The more diverse the industrial zone system's output is, the more prominent are industrial symbiotic networks that emerge. However, an ongoing review of network efficacy should be carried out.

4. Conclusions

Beverage, paper, and fisheries production dominate industrial activities, with noteworthy weight values ranging from 0.6 to 1 in the polygon synthetic indicator study. This signifies the viability of EIP growth in poor nations. However, the Vietnamese government, stakeholders, and foreign experts should evaluate how to improve heavy industrial operations such as heavy machinery manufacture, nonferrous metal refining, constructive productivity, and energy generation, among others. Similarly, more analysis of the outcomes of the three separate pilot initiatives in terms of electricity savings, material consumption, wastewater, and solid waste is needed. The index studied disclosed vastly different outcomes. Ninh Binh and Da Nang had a straightforward breakup by many indicator levels, with most variables surging with scores approaching 1. Others were negative or near to the lowest value (-1), which indicated the need for industrial symbiotic links to be improved. Moreover, the use of environmentally friendly technology has been backed by ground-breaking efforts and performance. The Vietnamese government has acknowledged and implemented the EIP program in recent years to foster growth and ecofriendly policies. It is critical to recognize that the

EIPs initiatives have preceeded under that leadership and with the cooperation of international organizations. The initiatives have shown the potential to significantly enhance Vietnam's economic, environmental, and energy security.

Besides, the integration of diverse industrial domains generally requires a diverse range of resource input and output flows suitable for inter-industry interactions. Therefore, combining enterprises of various sizes may aid in the growth of symbiosis by providing chances to valorize varying volume sources. Policies and regulations can assist increase resource productivity at the firm and industrial zone levels. As previously stated, some rules in Vietnam are now an obstacle to the creation of industrial symbiosis. Since by-products have been historically regarded as trash. Thus, growth is confined by severe restrictions that prohibit the unlawful disposal of contaminants.

The rewards of industrial symbiosis include risk mitigation, increased productivity, and better environmental and social performance, in addition to better returns on investment. As a result, financial decisions must be made after taking into account the complete range of economic, environmental, and social advantages. The adoption of industrial symbiosis necessitates a favorable return on investment and thus may be weak fruit for some beneficiaries, as their investment is commonly battling with investments in other fields. Significant investments are sometimes required to create industrial synergy. This is particularly true when it comes to utility synergies and shared infrastructure in industrial parks. Monetary incentives might assist in shortening the payoff.

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