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Industrial Ecology and Eco-Industrial Park: Models and Statistics with Implications to a Central Province in Vietnam

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ABSTRACT

Science and technology are witnessing remarkable progresses day by day. This is also the foundation of new production tools, which are capable of being more responsible for the environment, society and people's lives. Therefore, eco-industrial parks have been established all over in order to apply high technology to production and business without affecting the sustainability of the economy and the development of industry. In the world, the theory of Industrial Ecology as well as Eco-Industrial Parks (EIPs) has been researched and published by many authors with the important point is to measure the ecology in industry to find solutions for the development of the model. For Vietnam, Quang Ngai is becoming a bright spot for investment in high technology and Industrial Ecology, as well as the construction of EIPs. With qualitative research to clarify theoretical models of EIPs, the authors analyzed and identified the possibilities of developing EIPs according to the province's orientations and wishes. The thesis can conclude that this model being analyzed is indispensable for industrial development with specific central provinces such as Quang Ngai.

Keywords: Eco-Industrial Park; Industrial Ecology; Industrial Symbiosis; Sustainable Development; Vietnam

1. Introduction

Several industrial zones have been built in the last decades of the twentieth century with many different names: science park, science city, high-tech park, technology start-up zone, or even science village in many countries over the globe. In fact, at the moment the large universities or large enterprises are now also building many high-tech industrial and high-tech development facilities with the so-called names: incubator, initiator (spin - off), start-up. There are tens of thousands of high-tech parks in the world today. Thus, the appearance of high-tech zones is the beginning of the development of a new production force based on a high-tech system to form a modern production base, which is the basis of a new economy of digitalization. Furthermore, the old technological system which has been severely mechanized and chemicalized as in agriculture, for instance, to secure food and raw materials for industry, but has led agriculture to the brink of disasters such as deforestation, soil erosion, water depletion, ecological pollution by the use of chemicals. While the tragedy of poverty in most of the developing world, with its billion people, agricultural, rural, and unurbanized areas remain a vexing issue that governments must address.

In that context, the high-tech system with state-of-the-art sciences has become the direct production force. In the next few decades, there will certainly be new breakthroughs that enable us to change the quality of many production processes, increase labor productivity, create more and more new goods and services to serve human needs. About all of the existing industrial zones today, it is easy to recognize a fact that high technology has helped people perform tasks that were previously impossible when being done manually, with old-fashioned technology. That opens a period with many opportunities in establishing high-tech industrial parks to bring good things to people, communities, society, and even the ecosystem. One of which is also the ecological industrial park model that the article will focus on for a selected province in the central region of Vietnam.

2. Literature Review

2.1 Industrial Ecology

According to the first definition of industrial ecology (IE) by Frosch and Gallopoulos (1989) (a.k.a. "industrial ecosystem"), scholars have largely found that industrial ecology encompasses at least two main classes of meaning. Firstly, IE refers to industrial activities carried out in an ecosystem model that is natural and does not involve humans. It is a natural and effective mechanism for the reuse and recycling of resources used in industries, which is similar to a cyclical process of nature when resources have different mechanisms in self-regenerating and restoring very naturally. Second, IE emphasizes that human's economic - technical activities are not separate from the natural world, when it is covered by an ecosystem and it can also cause impacts back to the that natural ecology.

Reid Lifset (2009) has developed this theory by placing IE in the context of input-output economics with an interdisciplinary process of analysis to describe and evaluate the structure of the economy when there is an interaction between industries or between businesses and households (a.k.a. the inter-industry equilibrium model, proposed by Wasily Leontief in 1973 (Robert Dorfman, 1973)). The concept of output - input herein refers to the use of natural resources such as inputs for production and services, and as a result, outputs including by-products of the production process, shall be discharged into the environment and released into the atmosphere. Looking at the operation chain of the industrial production process, IE focuses on exploiting the organic relationship between the use of natural fuels at the input and the natural discharge of pollutants in the environment at the output. This is like a circular cycle of material forms in a symbiotic relationship among industries (Sangwon Suh, Shigemi Kagawa, 2009). Thus, the main task of an IE is to close that circle.

The idea of a 'closed-loop' in IE approach has been continued by Xiaohong Li in 2018. The circle starts with inputs of materials, energy, information information and even customers of the business. These input points are transformed during production and service provision by the interaction of employees, working equipment conditions, production technology, data and knowledge stores related to production owned by the business. The result of that transition creates goods, services, information, by-products, wastes and emissions into the natural environment. Within the traditional way of production, this is a simple linear process that does not protect the sustainability of the environment. Applying the concept of a closed circle in corporate governance, that relationship becomes closer, without ending, with the output of one stage becoming the input of another, creating the ability to regenerate, reuse, remanufacture products after use and preserve the sustainability of the natural environment. Figure 1 illustrates this.

At the starting point of the circle, materials are classified into groups that can and cannot be recycled within a certain time. Accordingly, the goal of the process of converting materials into finished products in enterprises should reach 100% recyclable materials. Management thinking must also be changed to create innovative solutions that, then, involve the use of wastes or by-products of production for other processes (e.g., making animal feed). The products of those processes are then used for the next when the enterprise can move towards a flow of transitioning to a new state of matter through regeneration, reuse or re-manufacturing of newly-finished products with commercial value through a mechanism, called DfE (Design for Environment). The product of this process can be pre-primed with renewable raw materials, or it can be commercialized and can also contribute to the generation of new supplementary energy sources.

Also in 2009, two professors of Waseda University (Japan), Shinichiro Nakamura and Yasushi Kondo, once again emphasized the input-output analysis approach to waste in building IE systems. Two scholars believe that there are two main tools in the analysis and assessment of industrial ecology: a product life cycle assessment (referred to as LCA, life cycle assessment, which includes research & development and distribution within production, along with use and disposal), and analytical methods material flow (referred to as MFA, material flow analysis) (Shinichiro Nakamura, Yasushi Kondo, 2009). However, Reid Lifset (2009) also mentions the Sustainable Consumption approach for evaluating and establishing a firm foundation for an IE.

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Firstly, the LCA approach follows the closed-loop circle of the product life-cycle with an input-output analysis model of the amount of waste and the environmental impacts of a product system. Often, this method is associated with inventory analysis for the product life cycle, with a specific amount of product used within T years and disposed of at the end of that life cycle (a.k.a. EoL, End of Life).

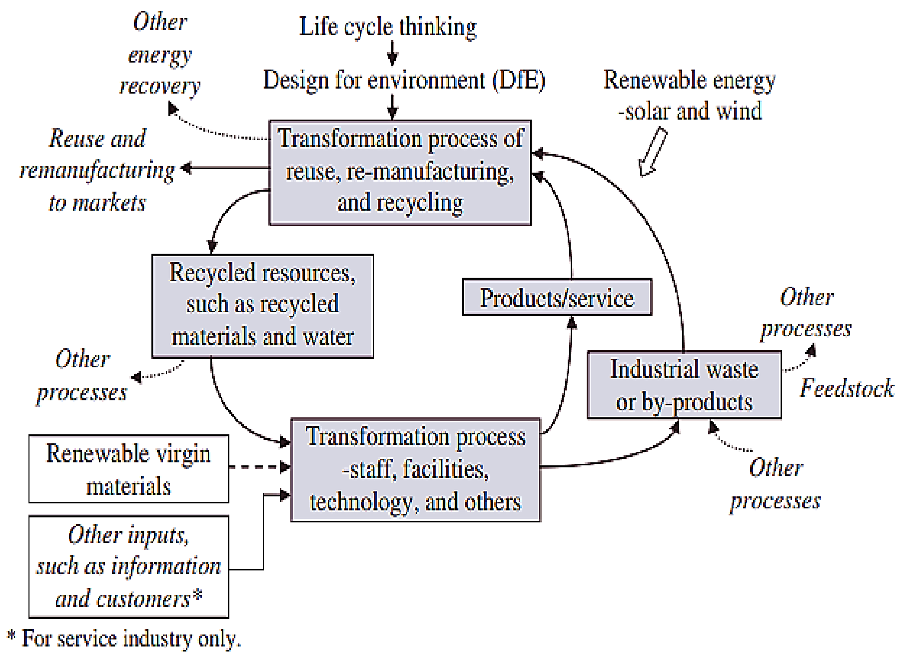

Figure 1: The closed-loop circle of an IE idea

Source: (Xiaohong Li, 2018)

Assume that we are interested in the life cycle of a product j that is used for T years only to be discarded at the EoL stage with a waste generated of l. We have a (n+m+p)x1 ordered vector for the process of using P^u_j with an input n ordered vector (a^u_j), a waste m ordered vector (g^u_j) and gas emissions p ordered vector (r^u_j). Then the coefficients (Alpha $\alpha^u_{ij}(t)$, Gamma $\gamma^u_{oj}(t)$ and Zeta $\zeta^u_{sj}(t)$) each in turn relate to input i, waste o, and emissions s respectively in each year of the t period of the using process. In fact, the effectiveness of a product can be reduced after a long time of use; for example, machines will need more inputs but are likely to emit more into the environment. Therefore, coefficients, such as $\alpha^u_{ij}(t)$, $\gamma^u_{oj}(t)$ or $\zeta^u_{sj}(t)$ are anchored to t time to account for fluctuations that may occur during the use of the product. In a simpler situation, however, we can eliminate that dependence and make these coefficients constants that do not change over the life of the product. The analytical matrix equation for the process used is:

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$$P_j^{\mathrm{u}} = \left(\begin{array}{c} a_j^{u} \\ \hline g_j^{u} \\ \hline r_j^{u} \end{array}\right) = \left(\begin{array}{l} \left.\begin{array}{c} \sum_{t=1}^{T} \alpha_{1\,j}^{\mathrm{u}}(t) \\ \vdots \\ \sum_{t=1}^{T} \alpha_{j-1\,j}^{\mathrm{u}}(t) \\ 1 \\ \sum_{t=1}^{T} \alpha_{j+1\,j}^{\mathrm{u}}(t) \\ \vdots \\ \sum_{t=1}^{T} \alpha_{n\,j}^{\mathrm{u}}(t) \end{array}\right\} \boxed{\text{Input}} \\ \hline \left.\begin{array}{c} \sum_{t=1}^{T} \gamma_{1\,j}^{\mathrm{u}}(t) \\ \vdots \\ \sum_{t=1}^{T} \gamma_{l-1\,j}^{\mathrm{u}}(t) \\ 0 \\ \sum_{t=1}^{T} \gamma_{l+1\,j}^{\mathrm{u}}(t) \\ \vdots \\ \sum_{t=1}^{T} \gamma_{m\,j}^{\mathrm{u}}(t) \end{array}\right\} \boxed{\text{Waste generation}} \\ \hline \left.\begin{array}{c} \sum_{t=1}^{T} \zeta_{1\,j}^{\mathrm{u+e}}(t) \\ \vdots \\ \sum_{t=1}^{T} \zeta_{p\,j}^{\mathrm{u}}(t) \end{array}\right\} \boxed{\text{Emission}} \end{array}\right)$$

When integrating the entire product life-cycle process into the formula, we have production (p, production), using process (u, use) and emitting process (e, emissions) on the same unit process formula for product j is as follows:

$$P_j^{p+u+e} = \begin{pmatrix} a_j + \breve{a}_j^{\mathrm{u}} + a_j^{\mathrm{e}} \\ g_j + g_j^{\mathrm{u}} + g_j^{\mathrm{e}} \\ r_j + r_j^{\mathrm{u}} + r_j^{\mathrm{e}} \end{pmatrix} = \begin{pmatrix} \breve{a}_j^{p+u+e} \\ g_j^{p+u+e} \\ r_j^{p+u+e} \end{pmatrix}$$

In which, $\breve{a}^{u}_{j}$ is a^{u}_{j} with the *j-th* element that is equal to 0.

Second, the MFA method is a way to make good use of the available data about the input materials and the finished product output of the production process. However, the integrated assessment of economic - environmental efficiency of this method is quite limited. The accuracy of the data for analysis is highly dependent on the quality and completeness of the data collected on a business, territorial, regional or national scale. Typically, input materials data are highly accurate, while data relating to trade flows and discharge and emissions flows are less accurate and complete. On the scale of an economy, Eurostat (2001) has proposed a model of the balancing mechanism for the flow of raw materials as shown in Figure 2.

In which, water and air flows often account for a very large amount of flow compared to others, so Eurostat also recommends separating these two flows to examine independently, together with domestic materials unused after extraction. In addition, for accurate and consistent measurement of material flows, calculation conventions must also be introduced; for example, in CO2 emissions, 27% is Carbon, and 73% is Oxygen.

Based on this model of Eurostat, other raw material flow metrics will be developed. Input indicators can be seen such as DMI (Direct Material Input, measuring direct input of raw materials), TMI (Total Material Input, including DMI and unused domestic extraction), TMR (Total Material Requirement, which measures both indirect flows through imports and TMI). Raw material consumption indicators can be seen such as DMC (Domestic Material Consumption, which measures the total direct domestic use of raw materials), TMC (Total Material Consumption, equal to TMR minus export flows and export-related indirect flows), NAS (Net Additions to Stock, which measures the total amount of raw materials added to an economy each year minus the amount destroyed or removed), PTB (Physical Trade Balance, which measures the physical balance of trade). Output indicators that can be identified are DPO (Domestic Processed Output, which measures the total amount of domestic raw materials used in the economy before 'flowing' into the environment), TDO (Total

Domestic Output, including DPO and unused portion of extract, DMO (Direct Material Output, including DPO and export), TMO (Total Material Output, including TDO and export).

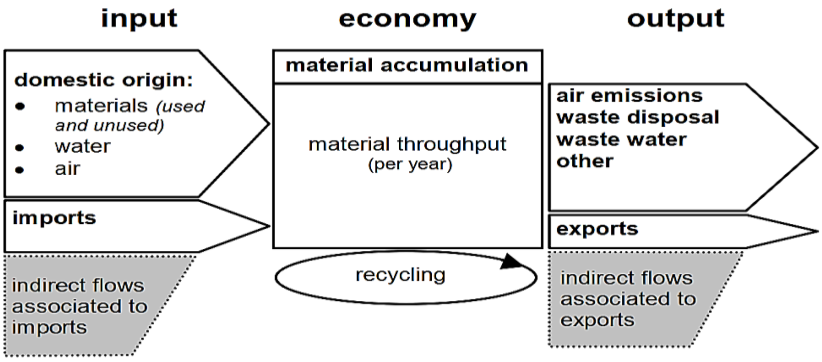

Figure 2: Simplified balancing mechanism for material flow

Source: (Eurostat, 2001)

Third, the sustainable consumption approach, introduced in 2009 by two scholars of the University of Sydney, Richard Wood and Manfred Lenzen, includes three main components: context analysis, ecological footprint assessment and structured decomposition. These methods also put themselves in the general problem of the input-output model, but the approach also suggests a different way of comparing, analyzing and commenting compared to the original version of the method. In this, context analysis is used to describe hypothetical states of the future to help identify problems and opportunities on the basis of comparisons between present and future, and even between hypothetical states. On one hand, it conducts the ecological footprint assessment that brings together environmental impacts from multiple perspectives into independent indicators to analyze the influences of past or present consumption levels on the ecosystem. On the other hand, structured decomposition applies data series over time and breaks down the influencing factors for a selectivity index into many independent constituents for analysis.

Thus, IE is a concept associated with the interdisciplinary relationship between many scientific fields such as ecological science, natural science, technical science, regional economics and even business administration, when we are interested in how business leaders must act to contribute to building an ecosystem in that industry. Understanding IE is very diverse from various sources and from many perspectives of researching scholars. However, in this topic, the authors proposes a general understanding of IE as follows:

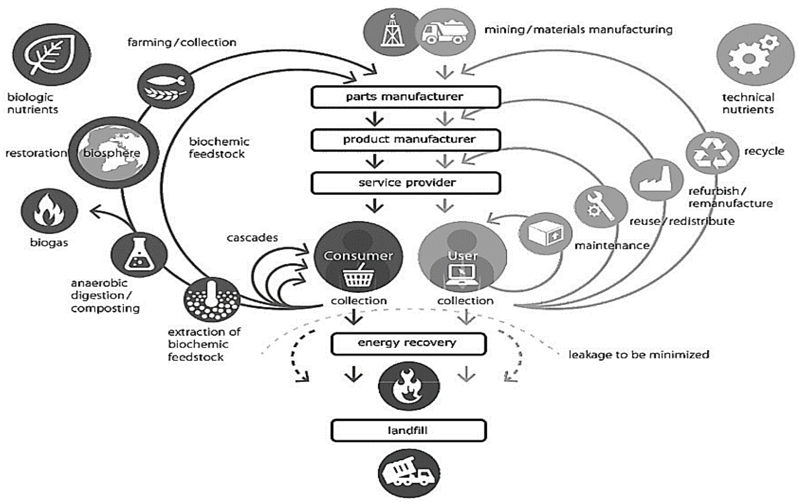

Figure 3: The Ellen MacArthur Foundation's Circular Economy Model

Source: (Delphine Gallaud and Blandine Laperche, 2016)

Industrial Ecology is the scientific field that studies industrial ecology, industrial symbiosis, biochemical processes in industry, and the process of creating rules and regulations for the development and application of ecological thought in the stages of industrial production, helping to shift from the industrial system to the industrial ecosystem in order to help maintain and promote its natural characteristics of a biological ecosystem.

With the above arguments about IE, we can realize that this concept, apart from considering the natural environment as the starting point for all product design ideas and the life cycle of products that businesses/economy produces, also uses the concept of circular economy in the process of integrating production stages into the context of the natural environment, ensuring the natural cycle of raw materials in the investment, production and consumption, reduction of substances and emissions, and preservation of natural resources (Jiansu Mao et al., 2018). Accordingly, IE contributes to the formation of a circular economy in a renewable and resilient economy, combined with a collaborative economy and a service economy to create a proper circular economy in the global context of new economic models (Laura Frodermann, 2018). This relationship can be identified more clearly through the model of the circular economy proposed by the Ellen MacArthur Foundation (Figure 3).

2.2 Eco-Industrial Park

2.2.1 Defined

The President's Council on Sustainable Development has submitted a Proceeding Report of the Conference on Eco-industrial Parks (EIP) organized at the end of 1996 for President Bill Clinton (Vesela Veleva et al., 2016). Accordingly, the first definition has been shaped by leading experts in the US and the world on eco-industrial parks. At that time, eco-industrial park has been most explained as a business community that cooperates with each other and with local authorities to share resources (information, raw materials, water, energy, etc.) infrastructure and natural habitats) to achieve the goals of economic, environmental quality, equitable development of human resources for businesses and for the local community (PCSD, 1997). This definition shows that cooperation between businesses plays an important role in achieving goals, especially environmental sustainability goals in an eco-industrial park. Thus, the highlight in an ecological industrial park is still to save energy, raw resources, and discharge norms to create good things for the ecological environment in general.

The United Nations Industrial Development Organization, UNIDO, in association with the World Bank and GIZ organization (Germany) have come up with a common definition of an eco-industrial park as an area reserved in a certain location for industry that ensures sustainability through the integration of quality social, economic and environmental aspects in site selection, planning, management and operation (UNIDO et al., 2018).

In 2021, UNIDO has again had an independent definition to affirm its own concise view of an eco-industrial park as a managed industrial activity area to strengthen inter-industry and community linkages for common interests including economic, social and environmental performance. Thus, we can see that even the leading organizations in industrial innovation believe that there should be a sustainable and close relationship within the pre-set areas for the creation of ecological industrial zones and the operation of industrial parks. The whole business system and community should not only care about environmental benefits, but should also pay attention to economic and social efficiency.

In this paper, we use the concept of eco-industrial park of the US President's Council on Sustainable Development (1997) because of the precedence and superiority of the member experts. Accordingly, when recognizing and assessing the ecology of an industrial park, the necessary conditions to ensure that an existing industrial park can be classified as an eco-industrial park include:

▪ Cooperation among enterprises in an industrial community: this is the key link when enterprises in industrial zones cannot exist alone without having connections with the others. The cooperation will solve many problems posed in creating an eco-friendly environment, especially the relationship between the output and input of waste and raw materials for industrial production.

▪ The cooperation between these industrial enterprises and the local government: this relationship is similar to the above relationship of enterprises with each other in that it helps to make better use of available resources like information, raw materials, water resources, energy, infrastructure and even the natural environment.

▪ The first goal of these industrial parks is economic efficiency. In which, enterprises must aim for profit in their production and business activities. The coordination with other businesses and with the local government helps to optimize production methods by reducing costs and increasing profit margin on each product created.

▪ The second goal of these industrial parks is environmental quality. This shows a binding relationship to achieve economic efficiency for member enterprises of the industrial park, providing that those profits, even big or small, must not harm the quality of the environment (water, air, and natural ecosystems).

▪ The third goal of these industrial parks is the equitable development of the people. They are the ones who are in the business as well as of the community. No matter what job they do, what social group they belong to, the opportunities for them to develop their best intellect, physics and mentality must be promoted by the member enterprises of the industrial park besides the goal of gaining profits and keeping environmental quality.

2.2.2 Establishment rules

Eco-industrial parks can be newly built or can be converted from the existing model of industrial zones of a region, territory or country. In 2018, the Central Institute for Economic Management (CIEM) also mentioned the world transformation and lessons for Vietnam in the Institute's Symposium Report 6. The report has stressed on the importance of institutionalizing the concept and defining criteria for eco-industrial parks through legal documents, and creating pilot mechanisms for monitoring and operating these industrial parks (Tran Trung Hieu, 2018).

UNIDO (2017a) also pointed out the requirements for the general framework of operation and maintenance of an ecological industrial park in the world with 5 groups of contents: (1) complying with national and regional legal regulations; (2) achieving industrial park management standards; (3) achieving the environmental effects; (4) achieving the desired social and community impacts and (5) achieving the expected economic performance.

In order to gain insight into the principles of eco-industrial park construction, we also need to consider the obstacles to this work. When the limitations are clear, the introduction of new rules becomes less rigid in implementation. UNIDO (2021) pointed out three groups of obstacles for eco-industrial parks: (1) legal obstacles, (2) technical and socio-economic obstacles, and (3) internal obstacles regarding the set capacity of the organization. Firstly, legal obstacles may come from the lack of policies on promoting the development of eco-industrial parks or the development and application of new generations of clean technologies or lack of transparency and publicity in the application of existing regulations. Secondly, financial constraints to implement pollution prevention mechanisms, lack of necessary support for breakthrough environmental solutions, lack of resources for research, or lack of understanding about corporate social responsibilities all create technical and socio-economic obstacles. Thirdly, corporate organizations also face a shortage of skilled technical workers, a lack of motivation for continuous improvements, a lack of necessary communication channels and support from the external partners or lack of necessary indicators and guidelines for the implementation.

To identify the most universal principles for the construction of an eco-industrial park, we also rely on the guidelines of UNIDO (2017b) as belows:

- Determine the most appropriate scope and priority activities within limited resources as well as the desires of stakeholders in the process of promoting the construction of eco-industrial parks.
- Promote understanding of the impacts, benefits and added values of the eco-industrial park project among public and private stakeholders.
- Strictly comply with legal regulations to get support from policy in deploying an eco-industrial park in terms of contents such as construction quality, rights and responsibilities in connection, energy usage, emissions, emissions

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limits, impacts on human health and the sustainability of nature, etc.

- Develop the organizational structure of management of eco-industrial parks in a sustainable way, addressing the diverse requirements of the process of industrial park construction and development.
- Ensure the necessary support from the technical aspect in testing, operating, measuring, monitoring and evaluating the technical and professional infrastructure of the eco-industrial park.
- Monitor progress regularly, periodically and transparently within a reliable mechanism.
- Strengthen the implementation capacity of stakeholders in the entire process of eco-industrial park construction and development, including technical and non-technical capacities.
- Ensure contributions to local communities and territories in order to create a healthy living and working environment, good for the health of people and future generations.

2.2.3 Evaluation criteria

Developing a common set of evaluation criteria for the eco-industrial park model is a very difficult thing because there are differences in the viewpoints of evaluating the process of formation, operation and maintenance results of the industrial park in the past few years from academics, certification bodies and policy makers. This is also due to differences in contexts and resources for developing eco-industrial parks in different countries and regions, so the criteria for this area may not be suitable for other regions.

ISO's criteria for the environment according to the sets of standards

The most modern set of standards on environmental management and environmental performance assessment can be mentioned is ISO 14031: 2021 (3rd version, replacing the second version of ISO 14031: 2013). The prominent method throughout this ISO 14031: 2021 set of standards is EPE (Environmental Performance Evaluation) to help evaluate environmental performance and EMS (Environmental Management System) to help establish an environmental management system in enterprises. EPE enables organizations to measure and evaluate against KPIs (key performance indicators) and effectively communicate environmental performance information. In addition, EMS allows businesses to assess the conformity of environmental performance previously measured by EPE with environmental policies or environment-related operational goals and objectives. In general, the groups of criteria evaluated by this standard are related to the following contents: organizational structure and leadership, planning related to the environment, activities to support the environment and operating the system, assessment of performance and upgrade, product system and product life cycle assessment (LCA).

In fact, the environmental standards of ISO not only stop at the set number 14031 but also relate to many other contents such as: environmental management system (ISO 14001:2015; ISO 14004; ISO 14005 and ISO 14006), environmental management (ISO 14015; ISO 14033; ISO 14040; ISO 14044; ISO 14045; ISO 14050:2020; ISO 14063), environmental labeling and declaration (ISO 14020; ISO 14021; ISO 14024; ISO 14025), greenhouse gases (ISO 14064-1; ISO 14064-2; ISO 14064-3; ISO 14067), and the EMS (ISO 19011) environmental management system or model of corporate social responsibility (ISO 26000).

As a United Nations organization in charge of industrial development in its member countries, UNIDO plays an active role in initiating and supporting EIP initiatives on a global scale. In Vietnam, the project "Implementing eco-industrial parks in Vietnam according to the approach from the Global Eco-Industrial Park Program" has been being carried out by UNIDO with the Ministry of Planning and Investment, and the Federal Bureau of Economic Affairs of the Swiss State (SECO). The three intend to initiate and implement the project within 36 months from the end of 2020 in 05 localities: Ho Chi Minh City, Can Tho, Dong Nai, Da Nang and Hai Phong.

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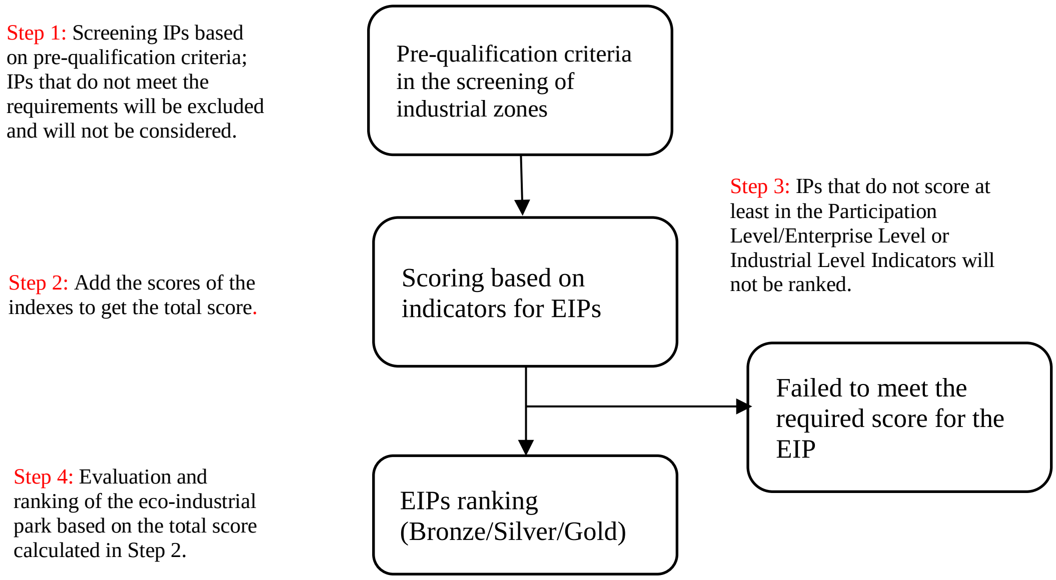

Figure 4: The process of evaluating and ranking eco-industrial parks (UNIDO Vietnam)

Source: (Trần Thanh Phương, 2018)

Criteria of UNIDO Vietnam

The EIP Scoring method proposed by UNIDO Vietnam aims to monitor the performance of Industrial Parks (IPs) on environmental sustainability through qualitative and quantitative criteria in order to minimize the burden on IPs and businesses. At the same time, the method provides an abundant source of information for the Vietnamese Government on the effectiveness of eco-industrial parks (Tran Thanh Phuong, 2018). This methodology classifies eco-industrial parks according to 3 levels: bronze, silver and gold. The classification is based on three important groups of indicators: the level of participation (the number of enterprises in the IP participating in the ranking process of the eco-industrial park), the enterprise-level index (the activities of participating enterprises with the data of at least carbon/water/waste), the index of industrial park construction unit level (licensing activity in recognizing an eco-industrial park).

2.2.4 Typical global EIP models

Devens is an industrial estate in the State of Massachusetts, United States. The neighborhood of more than 100 industrial enterprises operates on an area of only about 17.7 square kilometers but brings in more than 1.5 billion USD in revenue and more than 3,000 high-quality jobs for the community, even more than the number of people living in Devens. The Devens Enterprise Commission (DEC) has shaped a Devens to develop the vicinity towards an eco-industrial park with 07 main pillars: economic and business sustainability, society, and governance, public health, transportation, natural resources, and environmental quality (Vesela Veleva et al., 2016). In 2012, after a process of more than 10 years of building a sustainable industrial sector, DEC has decided to measure efficiency based on the group of 07 pillars mentioned above with 43 proposed criteria. The content of measurement and how these criteria are measured at Devens constitute a comprehensive set of criteria for assessing the industrial ecology of a system built with a long-term strategy and vision. The data are measured for the base year and the current year of the assessment. The assessment will focus on examining the differences between the original data and the current data to confirm whether the ecological characteristics are positive or negative.

In 1996, in his article about the concept of IE in the leading journal of energy and environment, Yale University chemistry professor, T. E. Graedel, mentioned the model of eco-industrial park that the Kalundborg ecological complex Denmark (Kalundborg Symbiosis) had applied since the 1970s. The model refers to the flows of resources within Kalundborg's

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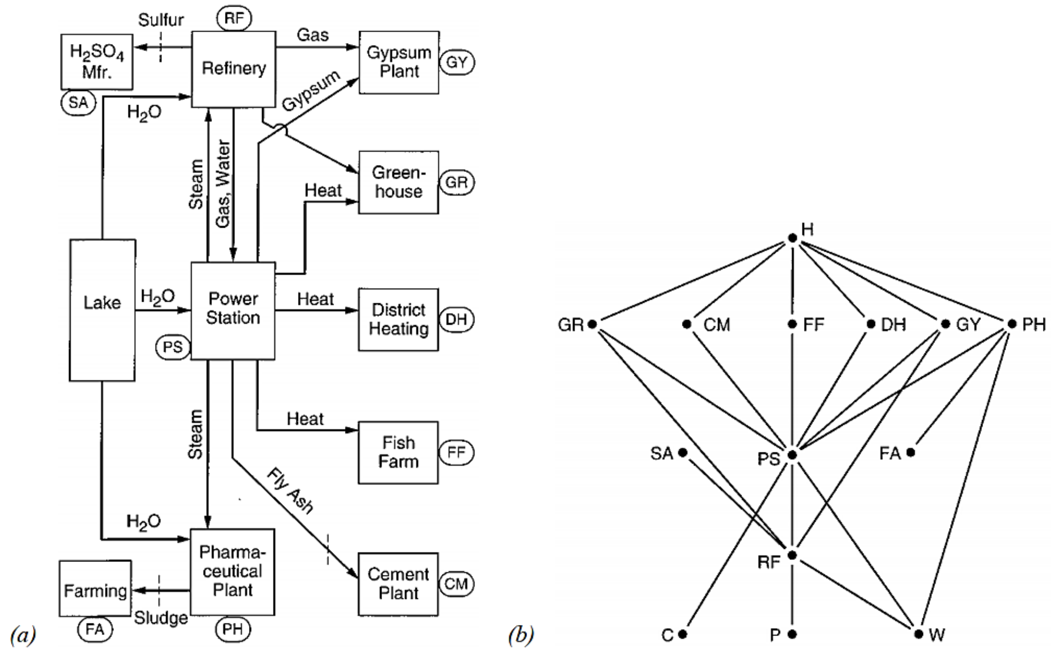
organic organization; in which, many resources are reused or converted into heat energy for both residential or commercial buildings within the Kalundborg region or transported for other uses outside of the area. That symbiosis comes from the fact that businesses and factories in this industrial cluster have found ways to cooperate with each other to share resources and utilize each other's waste to save fossil fuels, minimize environmental impact and minimize costs to achieve optimal economic efficiency. The model applies the image of the food web in the ecosystem to make the visualization of food layers (input materials) more specific with the highest layer for humans and the lowest layer for producers of water, coal and gasoline. The idea of using the food web to simulate the natural world in industrial production has been considered as a natural flow of transition from the traditional linear economic model to the circular economy. Whereas, linear food chains describe the flow of energy in theory, food webs describe more accurately and more realistically while considering the periodicity of the resources of materials and energy in the natural environment (Olcay Genc et al., 2019).

Figure 5 shows organic flows of raw materials that are by-products obtained from the production process of one enterprise and as inputs to the production process of another enterprise. For example, the Asnæs Power Station Coal-fired Power Plant uses excess heat to heat thousands of households in the area and nearby fish farms, while the fly ash from this thermal power plant is sold to the cement plant, the steam is sold to the Novo Nordisk pharmaceutical plant for insulin production and the Statoil refinery. The sulfur dioxide gas generated after coal combustion is recovered in the flue gas purification towers and separated into gypsum (Gypsum, CaSO4) and sold to Gyproc plasterboard factory. Waste from fish farm, biological waste after enzyme/insulin production and other biological products from Novo Nordisk factory are brought to fertilizer factory. Water for all these processes is taken from Lake Tissø and is circulated between these plants in the form of direct water, steam, and cooling water.



(a): Model of an organic symbiotic industrial complex. Loose lines mark resources that can be moved outside of Kalundborg to produce other products.

(b): Food web. H: human; C: coal; P: gasoline; W: water

Figure 5: Model of the eco-industrial park of Kalundborg, Denmark

Source: (T. E. Graedel, 1996)

However, we can see that this symbiotic connection process of enterprises in many different industrial fields also has limitations when it is necessary to have a coordination mechanism for that combination in a balanced way, whether within or outside the EIP. This requires the right infrastructure for connectivity, the right form of transport – logistics for transshipment, the right network of businesses that can be sorted into the food web as a natural connection. If they fail to do so, EIPs need to have very specific and detailed plans related to member enterprises so that they can actively call for investment. In fact, this job is not easy.

Also in 1996, Ernest A. Lowe et al. have cited the model of the EIP Evaluation Framework developed by Indigo Development a year earlier. This theoretical model is structured by four main groups of criteria: economic feasibility, technical feasibility, environmental performance and social impacts. The interference of those target groups are the design goals of the eco-industrial park; while those are measured with a focus on environmental performance in terms of use, emissions and interactions with the environment.

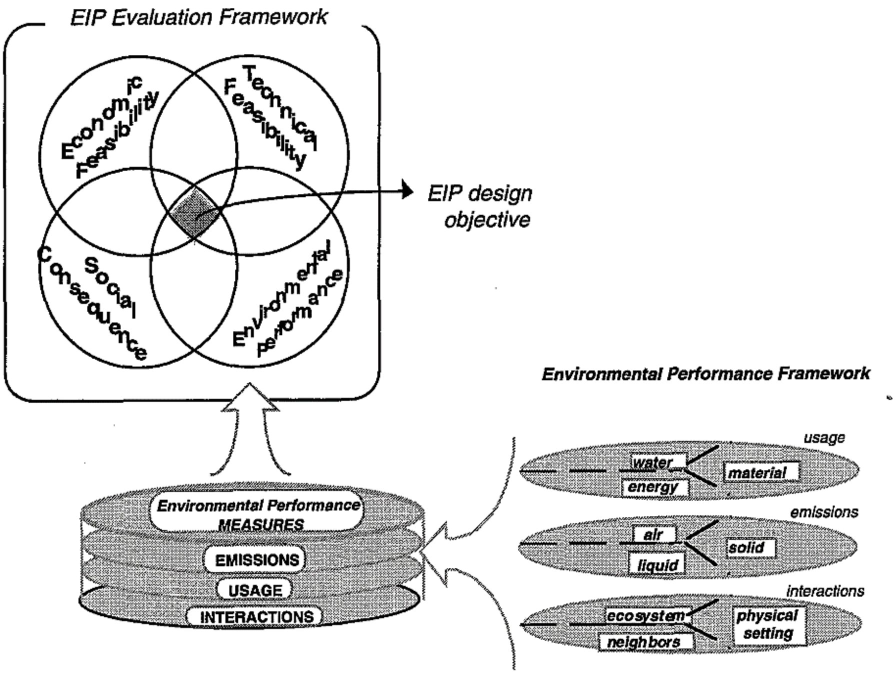


Figure 6: Eco-industrial park model of Indigo Development

Source: (Ernest A. Lowe et al., 1996)

The interaction layer is considered the foundation layer that needs to be measured with the effects on the ecological environment, the physical environment as well as the surrounding living environment of the IP. The operation process in production and business of the IP leads to the consumption of energy, water and other input materials; since then, businesses discharge waste into the air, land, water and solid waste into the natural environment. The process of measuring whether environmental performance meets those environmental, social, economic and technical objectives provides EIP managers with an updated perspective on design and operation of the IP, in the direction of ecology.

Afterwards, the study of Seleshi Sisaye (2011) went to analyze the ecological approach to sustainability and organizational accountability in its development process. In which, the standards of the Global Reporting Initiative (GRI) in 2008 on natural resource management, ecology and sociology as well as the collection of documents on the system environment (regarding the emission of hazardous waste and the use of natural resources) in compliance with ISO 9001 and ISO 1400, have been mentioned as a framework model for EIPs. In 2013, when analyzing the indicators to assess the contribution to the sustainable development of industrial zones in Mexico, Edgardo Bastida-Ruiz et al. also emphasized again that the standards set by GRI allow organizations to step by step report their environmental and social responsibilities to suit the regional and local context while these standards also promote coordination between businesses and organizations in the region or even at the same campus of an industrial park. At that time, the IP will gather an overall strength from its member businesses and be labeled "green", "clean", "socially responsible" or "ecological".

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Impacts	**Related indicators**
Economic	Economic performance
	Presence in the market
	Indirect economic effects
Environmental	Raw materials
	Energy
	Water
	Biodiversity
	Exhaust gas, waste water and garbage
	Products and services
	Compliance
	Carriage
Social: labor and employment	Recruitment Status
	Labor relations
	Occupational safety and hygiene
	Training and coaching
	Diversity and equal opportunity
Social: human rights	Diversity and equal opportunity
	No discrimination
	Freedom of association and collective bargaining
	Child labor
	Forced Labor and Compulsory Labor
Social: communities	Community
	Corruption
	Public policy
Social: corporate responsibilities	Health and safety of customers
	Product and service labels
	Marketing Communication
	Compliance

The indicators used to evaluate the GRI's standards are used as a theoretical framework in the survey questionnaires for activities towards ecology and sustainability in IPs when it comes to the criteria to be followed by the IP and its member enterprises, related to the economy, environment and society.

However, when applying this model of GRI, we realize that social aspects account for the majority of the indicators that need to be followed, monitored and evaluated; Meanwhile, environmental aspects, especially ecological diversity, have not been analyzed thoroughly. While analyzing the development situation of Devens EIP in USA, Vesela Veleva et al. (2016) also proposed a model of an ecological and sustainable Devens. The model revolves around 7 key pillars (economic and business sustainability, society, public governance, public health, transportation, natural resources, and environmental quality) as presented to help Devens pay full attention to all aspects and conditions to create a successful EIP (Figure 7). In terms of economic and business sustainability, Devens aims to attract investors and retain good organizations, creating jobs with high income for employees. In terms of social welfare, Devens is interested in creating sites that regenerate labor and develop diverse accommodation with prices so that at least 25% of the apartments are for workers to live in according to their financial ability. Here, Devens also aims to increase the number of people participating in the industrial park's general social events and has also become known for competing in a variety of movement-based sports at the recreational spaces for the available labor.

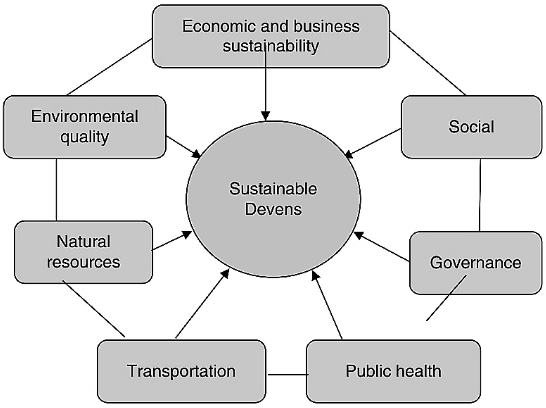

Figure 7: Model of Devens Eco-Industrial Park, USA

Source: (Vesela Veleva et al., 2016)

In addition, public governance for Devens includes 3 main objectives for the situation of an EIP; they are to connect people living in the premises of the industrial park, to accomplish what has been set out and to measure the results. Regarding public health, the IP is interested in health insurance for the population with common diseases, but when insurance is widely covered, the focus is on creating a social welfare space and training activities related to health improvement for the community. With regard to traffic and transportation issues, Devens has made outstanding progress since the 2000s with the establishment of a full range of green, clean and environmentally friendly transportation infrastructure to avoid air and water pollution, improving the public health index inside the IP, and protecting related natural resources. In order to protect natural resources, the EIP has to pays great attention to measuring and controlling the use of fuel resources such as water, land or energy, especially towards the construction of green buildings.. Environmental quality is also kept at satisfactory indicators in terms of air quality, solid waste, hazardous waste to the environment, land conversion rate, reuse, recycling and compost formation organic to reduce the emission rate at the utmost.

3. Methodology

The following qualitative and quantitative research methods can be used on a combined basis to clarify the research problems. This contributes to minimizing the inherent limitations in qualitative as well as quantitative research. Qualitative research will be further reinforced with objectivity of data and numbers in quantitative analyses; besides, the mechanical accuracy (depending on input data and sample typicality) can be neutralized when considering many other qualitative factors to adjust. It is a flexible combination of specific methods in two groups with each other according to the time decisions of the researchers to ensure the scientificity, the appropriateness of the research conditions, the research context and the possible unpredictable fluctuations during the study.

For this study, a secondary literature review method is used. Secondary data are the data that have been already available and were published through scientific researches in the same field, topics, project reports, documents issued by management levels, so it is easy to collect, less time and budget in the collection process. However, it is an important type of literature in the study of the social sciences. This method can be applied to work contents with many published documents of large enterprises, prestigious International Organizations, prestigious specialized scientific journals and legal documents. management of the Party's and State's agencies.

4. Implications and Discussion

Central Province of Quang Ngai and its industrial development directions towards 2025

The implementation of the Decision No. 998/QD-UBND of the People's Committee of Quang Ngai Province, dated 7/7/2021, on the promulgation of the Industrial Development Plan of Quang Ngai Province for the period of 2021 - 2025, the main tasks and solutions are to achieve To strive to make Quang Ngai province basically become an industrialized province in the direction of modernity by 2030 and in fact, Quang Ngai currently does not have a pilot industrial park to build an eco-industrial park with a system of infrastructure, technical and operational standards. Vietnamese standards and meet the global industrial park program to attract large enterprises to invest, exploit and do business, adapt to the trend of integration and sustainable development, contribute to promoting the development of the next-generation industry. period 2021 - 2025. This is also the main orientation that the Resolution of the 20th Quang Ngai Provincial Party Congress has set out.

The development of an eco-industrial park model that closely links between economic benefits and environmental protection is considered to be line with international trends. This direction, on one hand, is the rigid international commitments of Vietnam in general and of Quang Ngai in particular, and on the other hand is complied with international development programs such as economic development that must be truly sustainable (economical, social, and environmental) in accordance with the standards of a circular economy, a green growth or the standards in the Law on Environmental Protection (2020). In fact, in recent years, many countries around the world have succeeded with the eco-industrial park model, bringing new vitality to the economy, improving competitiveness in attracting FDI, and improving the living environment, working and living conditions of workers as well as local people where the industrial park is built.

As a result, Quang Ngai province has granted investment permission to 524 projects in the 2016-2020 period, with a total registered capital of 173,683 billion VND (equivalent to about 6.947 billion USD). In which, 123 projects are in the field of industry - construction (ratio of 23%) (QuangNgai PPC, 2021). The proportion of the value of industrial and high-tech products in the processing and manufacturing industries must reach at least 10%. The proportion of workers in the industry, construction and service sectors is over 63% of the total number of employees in the province; in which, the industry and construction sector reached about 30-32%. Industrial zones have created jobs and stable income for over 65,000 workers. Particularly, Dung Quat Economic Zone and Quang Ngai Industrial Parks have granted investment policies for 85 industrial projects. with a total investment of around 123,981 billion VND.

Vietnam's management framework for EIPs

In Vietnam's context, the Government has issued Decree No. 82/2018/ND-CP, dated 22/05/2018,covering the management content of EIPs in Section 4 of the Decree. Herein, 08 criteria to help determine the formation of an eco-industrial park are outlined in Article 42:

- Investors in industrial park infrastructure development and enterprises in IPs strictly comply with legal regulations on production and business, environmental protection and labor; encouraging investors to develop industrial park infrastructure and enterprises in industrial zones and to apply environment and production management systems according to the appropriate standards of the International Organization for Standardization (ISO).

- Investors, developing industrial infrastructure, should provide a full range of basic services in the IP in accordance with the law, including: essential infrastructure services (electricity, water, information, fire prevention and fighting) and other related services.

- At least 90% of enterprises in IPs have awareness of efficient use of resources and cleaner production, and at least 20% have applied solutions for efficient use of resources and cleaner production, and have innovated to improve management methods and production technology to reduce waste, pollutants, reuse waste and scrap.

- Investors have to set aside at least 25% of the industrial park's land area for trees, traffic, and shared service infrastructure according to construction standards of the Ministry of Construction.

- The EIP leaders must implement at least 01 industrial symbiotic association and at least 10% of the total enterprises in the park have plan to participate in those industrial symbiotic linkages.

- There are solutions to ensure housing and social, cultural and sports facilities for employees in the IP.

- Investors in industrial park infrastructure development and enterprises in the IP have a coordination mechanism to monitor the input and output of the IP on the use of energy, water, essential production materials, hazardous chemicals;

they also have to make annual reports on the results achieved in resource efficient operation and emission monitoring of the IP, and report to the Management Board of the Provincial IPs and economic zone development division.

- Each year, the investors who are developing the industrial park's infrastructure shall publish a report on environmental protection, social responsibility and contributions to the community around the IP to the Management Board of the EIP. The information should be posted on the website of the enterprise.

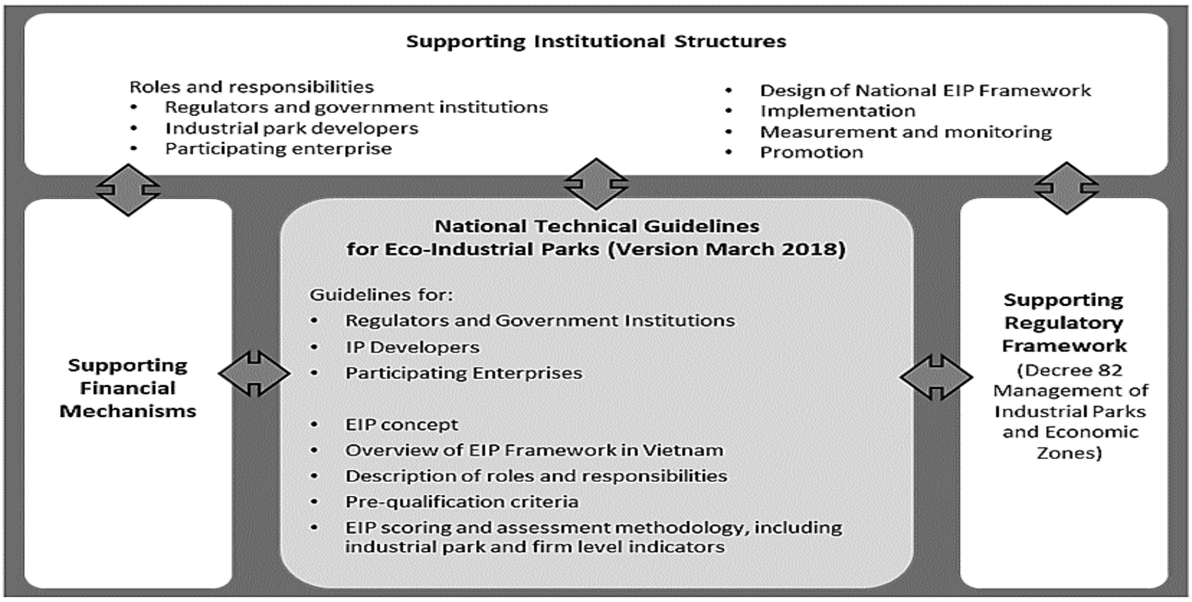

Figure 8: State management policy framework for eco-industrial parks in Vietnam

Source: (Jérôme Stucki et al., 2019)

In that, we see that the criteria have been initially quantified so that the state management agencies have clear goals in building new EIPs or transforming the existing industrial zones to EIPs. However, these quantitative numbers are only found in 03 out of 08 criteria, so the assessment of whether which IPs meet the ecological standards according to the law is still biased towards qualitative and subjective perspectives. The positive point that we see in this regulation is the adoption of international standards on the environment by ISO. However, we also need to understand that following ISO standards is still a process of imposing a top-down process in any organization, the results only exist in the form of right or wrong, not accepting the flexible improvisation and creative handling methods.

According to Jérôme Stucki et al (2019), the project of implementing the idea of EIPs towards building sustainable industrial zones in Vietnam in the period 2014 - 2019 has, in turn, accomplished the following main tasks with about 73 choosen enterprises: filtering IPs nationwide: identifying pilot projects of EIPs across the country, building capacity (state management, corporate governance, employees) to prepare for eco-industrial zones practice, piloting eco-industrial parks in industrial zones and industrial communities across the country, preparing policies and guidelines to transform existing IPs into EIPs, administering and evaluating the performance.

Figure 8 shows the policy framework of the Government of Vietnam for eco-industrial parks. In general, the focus of the policy is still on converting existing IPs with sufficient potential into eco-industrial parks in the future. The participation and cooperation between legislators and law enforcement as well as industrial park developers and businesses renting premises in IPs creates a support mechanism for policy implementation processes. Decree No. 82/2018/ND-CP is the most important document creating a legal premise in the implementation of EIPs across the country as it is a single specialized decree regulating the management of industrial zones and economic zones. However, the financial mechanisms to support the formation of eco-industrial parks are still a blur in terms of responsibilities and benefits between the parties involved.

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5. Conclusion

In summary, to be able to move forward successfully and take the initiatives in building EIPs, from the perspectives of an industrial province, Quang Ngai needs to (i) be aware of the inevitable and objective development trend of highly ecological Izs; (ii) meet the standards of EIPs, contents, characteristics, models, principles and criteria for building eco-industrial parks in the near future. This is considered a hard condition to attract technology enterprises from the US, Europe or OECD countries; (iii) study relevant legislation and legal corridors to quickly establish a roadmap for the next steps of the eco-industrial park. Provincial People's Committee first should include the Resolutions of the Provincial Party Council, the Standing Committee, the Resolution of the People's Council as a basis for formulating and implementing the projects of the Provincial People's Committee; (iv) conduct surveys and assessments to accurately state the current status of existing industrial zones and to propose plans to build, improve, maintain and supplement existing IPs to meet the requirements of eco-industrial parks, finding new industrial zones according to standards of an EIP; (v) promulgate the proposal of the Provincial People's Committee stipulating a specific roadmap and work to be implemented for agencies and units; (vi) promulgate incentives and advantages for mobilizing domestic and foreign resources in

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