2.6 Environmental indicators applied to reality of Eco-Industrial Park (EIP)

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Abstract

The Eco-Industrial Parks (EIP - Eco-Industrial Park) emerged as a new model of spatial organization for industrial arrangements. An important feature for an EIP is the adoption of the concept of industrial symbiosis (IS), in which companies reuse waste to reach a closed system, reducing environmental impact. The article describes an analysis of the environmental indicators used in EIPs through a systematic literature review (RBS). Results indicated that there are proposals to evaluate the waste stream and the symbiosis of an EIP through detailed indicators, which capture the need in a particular moment of time. The paper describes, compares and analyzes these proposals. As a result, it was shown that they have limitations described and exemplified in the text.

Keywords:

Eco-Industrial Park (EIP), Indicators, Industrial Symbiosis (SI), Systematic Literature Review (RBS).

1 INTRODUCTION

The Eco-Industrial Parks (EIPs) and Industrial Symbiosis (IS) process are in the field of Industrial Ecology, as fundamental tools, that harmoniously integrate the vision of the closed loop in a business ecosystem.

Seeking better utilization of by-products and waste treatment, the EIPs support the development of industrial symbiosis, highlighting the process as the main activities to be developed in an EIP.

The decisive factor for the success of an EIP is the determination of an organization to manage the EIP, known as an broker, whose role is to introduce the concept of symbiosis and encourage this practice. In addition, he is responsible for attracting viable businesses and gain the cooperation of all regulatory agencies. According Massard and Erkman [1], its function is to inform stakeholders on the issue of resource efficiency and waste exchange of promoting the sharing of experiences on the management of the flow identified, evaluating and implementing potential IS. But the most significant challenge is to define instruments direct to brokers that support systems and management practices in EIP [2] [3] [4] [5].

Some authors [2] [6] [7] [8] [9] have used indicators as a decision tool in EIPs, once they are able to provide information about physical systems, social and economic, allowing to analyze tendencies and cause-effect relationships over time.

The purpose of this paper is to examine indicators used in EIPs through a Systematic Literature Review (SLR).

2 METHODOLOGICAL ASPECTS

This work consists of an exploratory analysis of the state of the art of the Eco-Industrial Park concept and indicators used in EIPs. The methodological procedure adopted in this article was based on the Systematic Literature Review and followed the proposal of Conforto, Amaral and Silva [10]. The aim was to verify the existence of indicators that analyze, evaluate or collaborate in the management of an EIP.

The method used to carry out the SLR is divide into four stages. In the first stage, involving planning, the activities performed were: definition of the problem, definition of research goals, selection of primary sources, construction of search strings, definition of inclusion and qualification criteria and definition of the search methodology generating a research protocol. In the second stage, comprising execution, searches, data collection and application of inclusion criteria took place. The third stage, involving results analysis, consisted of the interpretation of the articles, summary of results and content analysis. Lastly, in the conclusion and introduction, articles were registered, consolidating the SLR results and developing theoretical models.

In this sense, we developed a protocol for a systematic literature review, which defined criteria for inclusion / exclusion of articles, and criteria for selection of indicators. The intention was to answer, especially the following question: What indicators are used to assess, analyze and contribute to the management of an EIP?

3 A REVIEW OF RELATED LITERATURE

3.1 Overview – Industrial Symbiosis Process in EIPs

The industrial symbiosis (IS) comprises industrial and commercial activities including the process of byproducts exchange as the main characteristic, seeking economic development, sound environmental planning, meeting the needs of neighboring communities and proper land use. Chertow [11] defines IS as the involvement of industries traditionally separated in a collective approach for competitive advantage including physical exchange of materials, energy, water and byproducts. The keys to industrial symbiosis are

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collaboration and synergy possibilities offered by geographical proximity.

There are currently few studies in the EIP literature and its definition is still undergoing an evolution process. Among the main materials, we highlight documents concerning specific EIP projects which provide a basis to further scientific studies. In practice, their implementation is even more emergent.

An eco-industrial park is:

"(...) a community of industries, businesses and services located in a common property. Its members strive to achieve the best environmental, economic and social performance through cooperation and environmental and natural resources management. Working together, the business community seeks a collective benefit greater than the sum of individual benefits the company would reach if it only improved its individual performance". Indigo Development [12].

The IS and EIP themes intertwine in that the process of IS is considered one of the main activities to be developed in an EIP. Based on thorough research of thirteen projects that were carried out by groups of students during the two years, Chertow [13] stated that the EIPs are a part of industrial symbiosis, highlighting it as a key feature.

The clarification of the advantages of IS is essential in the formation of EIPs, because works as attractive to implement the process in these environments. Benefits such as reducing the use of virgin materials, reduce pollution, reduce transportation costs of raw materials and waste management, greater community involvement, green marketing, sustainability, increase energy efficiency, increase the amount and types of process with a market value are recognized by many authors as Chertow and Lombardi [14], Geng et al. [6], Lowe [15] and Tudor et al. [16].

EIPs has been seen as an opportunity for companies to reduce their waste, recover values and achieve economies of scale in their production processes. Seuring [17] observes that increased competition in the international market has been a major driver for the establishment of EIP.

There is a worldwide interest in the implementation and development of EIPs. According to Indigo Development Institute [12], the public and private sectors began more than one hundred (100) EIP projects in Asia, Europe, Africa, North America, Latin America and Australia. The initiatives are at different stages of development. The reason of this different is the disparities of the economic reality of each country. In developing countries, such as Brazil, the government has supported projects to build new industrial parks. In already developed countries and linked directly to the current economic crisis, this new trend has brought the adaptation of existing industrial parks, seeking to transform them into EIPs.

An important issue in the analysis of these projects is that, in general, they do not adopt all elements featuring an EIP. Peck [18] reveals the absence of a specific methodology that defines what an EIP, and points out that the development of a clear definition would not only maintain their legitimacy, but also allow the park adjustments relating to their own local circumstances. Industrial parks have used this gap to classify themselves as EIPs.

Another question at issue concerns the lack of tools that support systems and management practices in EIP [2] [3] [4] [5], and as a result, difficult to accurately measure the development and operation of these parks.

3.2 Eco-Industrial Park as Dynamic Systems

There are several studies that suggest the use of methods and tools such as Life Cycle Assessment (LCA), Material Flow Analysis (MFA) and environmental indicators to characterize an EIP, measure the level of reuse of waste, eco-efficiency and environmental impacts in industrial parks. [6] [7] [9] [19]. However, these efforts have limitations that should be considered.

The tools have important features: result in absolute numbers, are accurate and can be compared across parks with different calculations. However, in the case of LCA for example, there is wide variation in the use of the criteria in the assessment of environmental impacts, requiring time to analysis and making it difficult to compare historical data with varying types of impacts.

This type of tool reflects a static view according to Chertow Ehrenfeld [20], once it provides a picture of the situation of the EIP in a given time, enabling to capture and "freeze" the situation in terms of the level of impact is EIP at a given time. These proposals also allow for future design a theoretical situation "more" symbiotic, indicating changes in processes and products to a set of specific companies. The limitation of this approach is in the form of analysis of the problem, where the EIP is viewed under a static point of view, not allowing initiate a set of actions to promote changes in EIP towards improving the situation identified. This is noted by the authors of the more recent proposals such as Wang, Feng and Chu [21] that admit the instability as a serious barrier to the appropriate development and progress of industrial symbiosis. Furthermore, tools are complex and requiring time for application and analysis.

The solution to this issue, and for the appropriate development of the field of industrial ecology, would be view the EIPs as dynamical systems [20]. Under this approach, the industrial environment is considered a dynamic system (complex adaptive), composed of companies and actors whose aims and goals are constantly changing, once they depend on market conditions and seek to reconcile various issues, such as economic benefits and their own desires. Abreu, Figueiredo Junior and Varvakis [22] explain that firms are open systems and are subject to change values and ideologies prevailing in the society in which it operates.

Chertow [23] shows that the industrial ecosystems have a strong dependence on market forces, and subject to rapid change, non-linear and discontinuous changes of direction, and must be seen as complex adaptive systems. For Tuddor et al. [16] companies can, over time, taking different paths and change their goals, thus affecting the functioning of the entire chain, developing a certain "fragile" system potential, once the dependency relationship between the companies do not necessarily ensure their survival, as the natural symbiosis. The company's move to another park may represent the biggest advantages that the current condition symbiotic can offer. The interaction in industrial parks is an opportunity in this regard.

4 SYSTEMATIC LITERATURE REVIEW – INDICATORS USED IN ECO-INDUSTRIAL PARKS

Some papers discuss about the use of environmental indicators for EIPs. The indicators are applied in the evaluation of the companies individually, or in the evaluation of the park as a system. According Sendra, Gabarrell e Vicent [8], there are many problems arise when implementing Industrial Ecology in industrial areas. They show that indicators are necessary and useful in order to objectively reflect and measure the constant evolution of this areas, it can structure and simplify systems data.

In an attempt to convert an existing industrial area in Spain in EIPs, the authors adapted the methodology Material Flow Analysis (MFA) proposed by Eurostat [24], widely used to analyze the social metabolism industrial and evaluate industrial parks and companies, and complemented with indicators of energy and water. The authors, through a case of study, used this indicators to detect companies with high consumption or inefficiency and evaluate the efficiency of some strategies in the conversion of an industrial area in Catalonia (Spain) in an EIP. The use of indicators allowed the detection of critical points of the system, such as resource consumption (Direct Material Input, Total Material Requirement, Water Input Total, Total Energy Input) and the use of own resources system (domestic versus imported), generation waste (or Total wastes Generation Material Inefficiency) and efficiency (Eco-efficiency or Eco-Intensity).

According to the authors, the process of transformation of an industrial park in EIP is slow and progressive, requiring the same goals among individual companies and the collective system and the use of indicators to measure this evolution.

Geng et al. [6] presented the model of circular economy based in China and discussed environmental performance of projects in the industrial areas. The authors explain that the implementation of EIPs has emerged as a project to support the policy of Chinese circular economy, currently having over fifty pilot projects in progress. The authors presented four groups of indicators applicable in Chinese industrial parks to measure their eco-efficiency: economic development indicators, indicators of material reduction and recycling, pollution control indicators and indicators related to the management of the park.

Later, Geng et al. [7] proposed a system of twelve indicators categorized into four groups. Four indicators for the outflow and four consumption category, two indicators for the integrated resources and two for the disposal of waste and emissions. The MFA was selected as the primary method to develop such indicators and other tools such as eco-efficiency indicators, were also taken to measure the environmental performance related to economic performance, especially for the use of water, energy and waste generation. The authors conclude that the application of this system may contribute to greater attention from local governments on environmental issues and to achieve economic, environmental and social benefits. However, there are significant barriers, such as how to implement this system, the lack of specific indicators of SI and social indicators, and the lack of studies that show significant results of deploying this system of indicators.

Kurup and Stehlik [9] applied in a practical case, an evaluation model for EIPs to measure the benefits of industrial symbiosis in the environmental, social and economic dimensions. To evaluate the efficiency of the method, the authors developed indicators to measure some aspects of each dimension. To measure the environmental benefits, the indicators used were: resource conservation, resource security, water contamination, dust emission, noise and air emission impact. To measure the social benefits, the indicators used were: productivity, retention of employees, job security / creation, sharing occupational health and safety programs' investment in research and development, sharing of infrastructure and technology, sharing of human resources, employee relations management, information sharing between companies, perception of communities in regards to environmental health, communication about the project in the community, partnership of educational opportunities for school children, employment opportunities, complaints from community, sharing of information between community and industries, level of understanding about IS projects among the community, opportunities of public relations, networking between industries and communities. And finally, to measure the economic benefits, the indicators used were: business opportunities, infrastructure for industries, for public infrastructure, labor costs, equipment costs, raw materials costs, compliance costs, permit costs, cost of penalties / fines and cost of future liabilities.

The authors highlighted the lack of studies to measure the relationship between stakeholders and study the common rules that help organizations and communities to work more efficiently.

Pakarinen et al. [19] analyzed the development of sustainability in a case of industrial symbiosis in Finland during the historical period of 1890-2005. The study is the practical application of the IS condition analysis system proposed by Sokka et al. [25]. Through this system the authors have identified and selected measurable indicators for each the four conditions. For each of the system conditions was chose to focus (non-renewable resources, emissions to nature, land use, impacts on human health and society) that steered the selection of indicators. For non-renewable resources were selected indicators related to metal recycling, waste and utilization of byproducts and fuel use. To emissions were considered specific chemical emissions and the treatment and recycling of these wastes. For land use used the amount of logging and minerals. And finally, impacts to human health and society, the authors considered the risks to health with specific products and social benefits through cooperation with the municipality. For the authors, the indicators presented in the case study can be a starting point for the analysis of aspects involved in the process of industrial symbiosis.

According Pakarinen et al. [19], the development of industrial ecosystems can be differentiated into three stages : Type I is an undeveloped system in which processes are linear—there are no feedback flows yet. In Type II a few feedback flows exist but the degree of exchange is still limited. In Type III material flows are almost cyclical: waste is used as a resource for other system components, therefore little waste leaves the system. The historical period presented in this study was framed in stages of development of industrial ecosystems and analyzed according to specific indicators focus on the condition of systems. The indicators used in this study showed that the case symbiosis developed in many ways towards better sustainability

Zhu et al. [2] developed a method of selection of companies interested in participating in an EIP which included the implementation of a system of indicators, providing a quantitative method to assess the adequacy of the company in an EIP to increase efficiency and stability systemic. The system consists of seven primary indicatiors, that are the key factors to consider by stakeholders of EIPs, and twenty-seven secondary indicators, that measure the profiles of each primary indicator. The indicators constitute a hierarchical structure. The indicators were divided according to a perspective based on the park and a perspective based on individual companies. For the first perspective, the authors considered as primary indicators: Matching with existing industrial chains, Park carrying capacity and Park environment performance improvement. For the second perspective, were considered indicators: eco-design, economic benefit, resources utilization and pollutants production.

Through the case study in a Chinese EIP, the authors applied the system of indicators in five candidate companies to assess their functionality these companies. The Analytic Hierarchy Process (AHP) method was used to generate weights to the seven primary indicators. For the authors, the access indicator system provides honest evaluation items for the stakeholders. In the indicator set, the most important one is the index of matching with existing industrial chains because it measures the enhancement of industrial symbiosis.

The authors concluded that the system provides a direct evaluation for the stakeholders of EIP.

5 DISCUSSION

The development of EIPs and support tools for brokers of industrial parks is still an emerging issue. In this sense, the work identifies the environmental indicators used that contribute to the management of an EIP.

The survey indicated that all studies consider symbiosis as a key element in the theoretical definition of EIPs. Also presented the results of an RBS which identified environmental indicators used for the evaluation of eco-industrial parks. It was identified the following characteristics: the scope of environmental dimensions treated is significant, and the focus has been on assessing the environmental performance combined with economic performance.

The analysis of these studies indicated that the proposed indicators measure the performance of a park at a given moment and discuss the accuracy and precision of these measures. They assist in the evaluation of the symbiosis, but indirectly by assessing specific aspects of metal recycling, nature emissions, fuel usage, use of waste.

Therefore, they do not explore how these data can be used for decision making of brokers, or serve as an incentive to change the status of the symbiosis, specifically. For this would need to consider the dynamic changes over time. This is called a static perspective in this research.

The maintenance of the studies in this perspective can be an obstacle to the improvement of industrial symbiosis, because more than measure, it is necessary indicators that can serve as incentive instruments, capable of generating a dynamic environment for collaboration and improvement in the level of symbiosis.

6 CONCLUSION

The Table 1 is a summary of key indicators used in EIPs.

Considering these results, we can conclude that this research identified an important theoretical gap: the need for proposals for indicators or indicator systems that consider a dynamic view of the problem, and indicators that go beyond measuring performance in a given time and may: 1) show the evolution of IS in the park over time, and 2) to compare the contribution of each company for this performance, serving incentive for the brokers of the park.

The work also indicates a contradiction studies. Although all articles and definitions recognize the process of industrial symbiosis as the main element of an EIP, the proposed indicators do not consider this perspective changes over time, which would be essential for the incremental improvement of IS in the park. We propose future research that can generate a parameter for evaluating the level of symbiosis over time.

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Table 1. Result of Systematic Literature Review

Authors	Indicators
Sendra, C.; Gabarrell, X.; Vicent, T., 2007	Adapted the methodology Material Flow Analysis (MFA) proposed by Eurostat [24], widely used to analyze the social metabolism industrial and evaluate industrial parks and companies, and complemented with indicators of energy and water
Geng, Y.; Zhang, P.; Côté, R.; Fujita, T., 2009	The authors presented four groups of indicators applicable in Chinese industrial parks to measure their eco-efficiency: economic development indicators, indicators of material reduction and recycling, pollution control indicators and indicators related to the management of the park.

Geng, y.; Fu, J.; Sarkis, J.; Xue, B., 2012	System of twelve indicators categorized into four groups. Four indicators for the outflow and four consumption category, two indicators for the integrated resources and two for the disposal of waste and emissions.
Kurup, B.; Stehlik, D., 2009	To measure the environmental benefits, the indicators used were: resource conservation, resource security, water contamination, dust emission, noise and air emission impact. To measure the social benefits, the indicators used were: productivity, retention of employees, job security / creation, sharing occupational health and safety programs' investment in research and development, sharing of infrastructure and technology, sharing of human resources, employee relations management, information sharing between companies, perception of communities in regards to environmental health, communication about the project in the community, partnership of educational opportunities for school children, employment opportunities, complaints from community, sharing of information between community and industries, level of understanding about IS projects among the community, opportunities of public relations, networking between industries and communities. And finally, to measure the economic benefits, the indicators used were: business opportunities, infrastructure for industries, for public infrastructure, labor costs, equipment costs, raw materials costs, compliance costs, permit costs, cost of penalties / fines and cost of future liabilities.
Pakarinen, S.; Mattila, T.; Melanen, M.; Nissinen, A.; Sokka, L., 2010	Through this system the authors have identified and selected measurable indicators for each the four conditions. For each of the system conditions was chose to focus (non-renewable resources, emissions to nature, land use, impacts on human health and society) that steered the selection of indicators. For non-renewable resources were selected indicators related to metal recycling, waste and utilization of byproducts and fuel use. To emissions were considered specific chemical emissions and the treatment and recycling of these wastes. For land use used the amount of logging and minerals. And finally, impacts to human health and society, the authors considered the risks to health with specific products and social benefits through cooperation with the municipality.
Zhu, L.; Zhou, J.; Cui, Z.; Liu L., 2010	The system consists of seven primary indicatiors, that are the key factors to consider by stakeholders of EIPs, and twenty-seven secondary indicators, that measure the profiles of each primary indicator. For the first perspective, the authors considered as primary indicators: Matching with existing industrial chains, Park carrying capacity and Park environment performance improvement. For the second perspective, were considered indicators: eco-design, economic benefit, resources utilization and pollutants production.

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