


**SUSTAINABLE INDUSTRIAL PARKS AND THEIR IMPACT IN ECUADOR: A  
SYSTEMATIC REVIEW OF THE LITERATURE**

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ARTICLE INFO	ABSTRACT
<p><b>Article history:</b></p> <p><b>Received</b> 24 July 2023</p> <p><b>Accepted</b> 17 October 2023</p>	<p><b>Purpose:</b> The objective of this study focused on conducting a systematic literature review (SLR) of Sustainable Industrial Parks (SIPs) and their impact in Ecuador.</p> <p><b>Theoretical Framework:</b> SIPs are an effective tool for implementing Inclusive and Sustainable Industrial Development (ISID) and are an instrument to increase impact with efficient use of resources and cleaner production.</p>
<p><b>Keywords:</b></p> <p>Blended Learning; Management Education; Executive Education; Bibliometric Analysis; Management and Business Education; Ecuador; Pollution; Circular Economy; Industrial Symbiosis; Sustainable Industrial Parks; Sustainability.</p>	<p><b>Design/Methodology/Approach:</b> The methodology adhered to three widely accepted steps for a SLR comprising: planning, execution and dissemination of the analysis. The data review period dates from January 1, 2003 to October 31, 2022, using crawlers such as Scopus, ScienceDirect, Web of Science and Dialnet, considering rigorous methods of inclusion and exclusion.</p> <p><b>Findings:</b> The results of this study have provided evidence towards the design of a Circular Economy (CE) integration model through Industrial Symbiosis (IS), with agent-based modeling (ABM) adapted to the authenticity of the Ecuadorian industry and to manufacturing with a sustainable mentality.</p> <p><b>Research, Practical &amp; Social implications:</b> This research through the RSL extracted essential information that highlighted and unified different concepts of SIPs, the congruent point of its functionality and the signs of change that Ecuador shows framed under the concept of CE, beginning to an era of transition extinguished mainly to the current four dimensions of sustainability, focused on economic values, environmental, social and political aspects.</p> <p><b>Originality/Value:</b> The current study contributes to the literature by showing that industrial development involves pollution and reducing it awakens the use of methodologies aimed at satisfying sustainability needs without involving the capacity of future generations.</p>
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## PARQUES INDUSTRIAIS SUSTENTÁVEIS E SEU IMPACTO NO EQUADOR: UMA REVISÃO SISTEMÁTICA DA LITERATURA

### RESUMO

**Objetivo:** O objetivo deste estudo centrou-se na realização de uma revisão sistemática da literatura (SLR) sobre Parques Industriais Sustentáveis (SIPs) e seu impacto no Equador.

**Enquadramento Teórico:** Os PIS são uma ferramenta eficaz para implementar o Desenvolvimento Industrial Inclusivo e Sustentável (ISID) e são um instrumento para aumentar o impacto com o uso eficiente de recursos e uma produção mais limpa.

**Desenho/Metodologia/Abordagem:** A metodologia seguiu três etapas amplamente aceitas para uma RSL que compreendem: planejamento, execução e divulgação da análise. O período de revisão dos dados vai de 1º de janeiro de 2003 a 31 de outubro de 2022, utilizando crawlers como Scopus, ScienceDirect, Web of Science e Dialnet, considerando métodos rigorosos de inclusão e exclusão.

**Resultados:** Os resultados deste estudo forneceram evidências para o desenho de um modelo de integração de Economia Circular (EC) através de Simbiose Industrial (SI), com modelagem baseada em agentes (ABM) adaptada à autenticidade da indústria equatoriana e à fabricação com um mentalidade sustentável.

**Implicações de pesquisa, Práticas e Sociais:** Esta pesquisa através da RSL extraiu informações essenciais que destacaram e unificaram diferentes conceitos de SIPs, o ponto congruente de sua funcionalidade e os sinais de mudança que o Equador mostra enquadrado no conceito de CE, iniciando uma era de transição extinguiu-se principalmente para as atuais quatro dimensões da sustentabilidade, focadas em valores econômicos, aspectos ambientais, sociais e políticos.

**Originalidade/Valor:** O presente estudo contribui para a literatura ao mostrar que o desenvolvimento industrial envolve poluição e sua redução desperta o uso de metodologias que visam satisfazer necessidades de sustentabilidade sem envolver a capacidade das gerações futuras.

**Palavras-chave:** Aprendizado Híbrido, Educação Gerencial, Educação Executiva, Análise Bibliométrica, Gestão e Educação Empresarial, Equador, Poluição, Economia Circular, Simbiose Industrial, Parques Industriais Sustentáveis, Sustentabilidade.

## PARQUES INDUSTRIALES SOSTENIBLES Y SU IMPACTO EN ECUADOR: UNA REVISIÓN SISTEMÁTICA DE LA LITERATURA

### RESUMEN

**Propósito:** El objetivo de este estudio se centró en realizar una revisión sistemática de la literatura (SLR) sobre los Parques Industriales Sostenibles (SIP) y su impacto en el Ecuador.

**Marco teórico:** Los SIP son una herramienta eficaz para implementar el Desarrollo Industrial Inclusivo y Sostenible (ISID) y son un instrumento para aumentar el impacto con el uso eficiente de los recursos y la producción más limpia.

**Diseño/Metodología/Enfoque:** La metodología se adhirió a tres pasos ampliamente aceptados para una SLR que comprenden: planificación, ejecución y difusión del análisis. El período de revisión de datos abarca del 1 de enero de 2003 al 31 de octubre de 2022, utilizando rastreadores como Scopus, ScienceDirect, Web of Science y Dialnet, considerando métodos rigurosos de inclusión y exclusión.

**Hallazgos:** Los resultados de este estudio han aportado evidencia hacia el diseño de un modelo de integración de Economía Circular (CE) a través de Simbiosis Industrial (SI), con modelamiento basado en agentes (ABM) adaptado a la autenticidad de la industria equatoriana y a la manufactura con un mentalidad sostenible.

**Investigación, Implicaciones prácticas y Sociales:** Esta investigación a través del RSL extrajo información esencial que resaltó y unificó diferentes conceptos de los SIP, el punto congruente de su funcionalidad y las señales de cambio que muestra el Ecuador enmarcado bajo el concepto de EC, iniciando una era de La transición se extinguió principalmente hacia las actuales cuatro dimensiones de la sostenibilidad, centradas en los valores económicos, los aspectos medioambientales, sociales y políticos.

**Originalidad/Valor:** El presente estudio contribuye a la literatura al mostrar que el desarrollo industrial implica contaminación y reducirla despierta el uso de metodologías orientadas a satisfacer necesidades de sostenibilidad sin involucrar la capacidad de las generaciones futuras.

**Palabras clave:** Aprendizaje Semipresencial, Educación en Gestión, Educación Ejecutiva, Análisis Bibliométrico, Gestión y Educación Empresarial, Ecuador, Contaminación, Economía Circular, Simbiosis Industrial, Parques Industriales Sostenibles, Sostenibilidad.

## INTRODUCTION

Humanity is currently facing a multidimensional crisis that threatens the continuity of life and the functioning of society as we know it, given the enormous negative impacts that our linear system of production and consumption is generating on a planetary scale, affecting from the environment to communities, the economy and political systems (Muyulema-Allaica & Ruiz-Puente, 2022). Developing countries have practically equaled developed countries in the percentage of CO<sub>2</sub> they emit into the atmosphere, especially those derived from industrial production, including water and air pollution, exposure to chemicals, waste, among others (Dwiharto & Kurniasih, 2023; Riyadh et al., 2022). Industrial parks can represent an alternative to address these issues, not only by addressing environmental problems but also by generating social and economic benefits at the company and community levels (Hu et al., 2022). In Ecuador, Industrial Ecology (IE) is presented as an economic challenge in basic industries because of the situation of unacceptable transformation in essential techniques of environmental support, giving foundation to the idea of creating interrelationships between products and consumers, defining what is considered usable and what is not (Muyulema-Allaica, 2018), another factor of analysis is the reconfiguration of the manufacturing movement that solves environmental events and improves production systems, among these methodologies is the IS, which plays a precise role in motivating the exchange of materials and energies between entities (Hasang-Moran et al., 2021; Vega-Quezada et al., 2017). The application of PaIS in Ecuador is considered relevant because of the need to achieve a sustainable productive environment where natural resources are consumed efficiently, reducing the environmental impact that over the years has become an increasingly urgent issue to solve, considering that the study is urgent due to the scarcity of information that the country shows as a result of an exhaustive literary review, even knowing that there is a gap to inspire change. Given this context, the objective of the research is to carry out an SLR on PaIS and its impact in Ecuador, as few studies that synthesize the importance of inclusion of a company can have when involved in PaIS groups and the number of existing empirical studies that apply the notion of PaIS in contexts of transition and innovation in the industry have been revealed. Thus, this study contributes to both academic and practical advances, as academics and practitioners can balance their efforts in the four dimensions of sustainability. This research was carried out taking into account that industrialization generates processes of ecological transition in companies, since they must carry out activities for the benefit of the SD, i.e., balancing economic growth, sectoral policy, social prosperity, the use of natural resources and the

environment, due to the close relationship between societies and businesses, which leads to a shared responsibility capable of categorizing a civilized society. Emphasizing that humanity in measures of development forgets the sustainability product of ignorance that generates low level of valuation towards the environment creating negative impact for society and nature.

## **THEORETICAL REFERENTIAL**

The Industrial Revolution has recorded in its origin phenomena of a technological and economic nature, presenting radical alterations in the secondary sector and in commercial logistics connections, besides accelerating the style of adaptation, work, interaction between people, including their lifestyle (Beltrami et al., 2021; González et al., 2019; Han et al., 2022). *Inquiries into the Nature and Causes of the Fortunes of Nations* (1776) written by Adam Smith, establishes an instinctive causal relationship between industrialization, increase of wealth and development of States, which despite developmentalist conjectures of the 1950s in the 20th century have persisted (Aparicio, 2013; Calduch-Cervera, 2006; Hosan et al., 2022; Martinico-Perez et al., 2018).

An archaic and conservative tool of planned economic development in developed countries is the industrial park (Aparicio, 2013; Benachio et al., 2020; Farrell & Löw Beer, 2019; Mustafa-M et al., 2021; Van der Biest et al., 2020). In recent decades, sustainable development (SD) challenges have become inseparable from industrial parks (Farooque et al., 2022; Gómez-Martín et al., 2018; Woldu, 2022). In fact, the design, development, management and modernization of industrial parks are cross-sectoral efforts involving a variety of stakeholders (Ishola, 2019; Jez et al., 2011; Mastrocinque et al., 2022; Mestanza et al., 2018; Van der Biest et al., 2020). In support of SD; Circular Economy (CE) and sustainable industrial parks (PaIS), industrial eco-parks or sustainable industrial parks can guide a more sustainable industrialization (Farooque et al., 2022; Reyes-Soriano et al., 2022; Woldu, 2022). They promote cooperation between multiple plants through resource sharing, waste integration and the use of sustainable means in order to transform the structure and operation of industrial parks from traditional linear (open-loop) to circular (closed-loop) systems, where waste is reduced and reused as input for other processes (Hu et al., 2022; Le Tellier et al., 2022).

The United Nations Industrial Development Organization (UNIDO) promotes and encourages participatory sustainable industrialization in countries with economies in transformation due to the constant emission that industries provide in water and air pollution, exposure to chemicals, wastes, among others. This proposes the PaIS as an effective

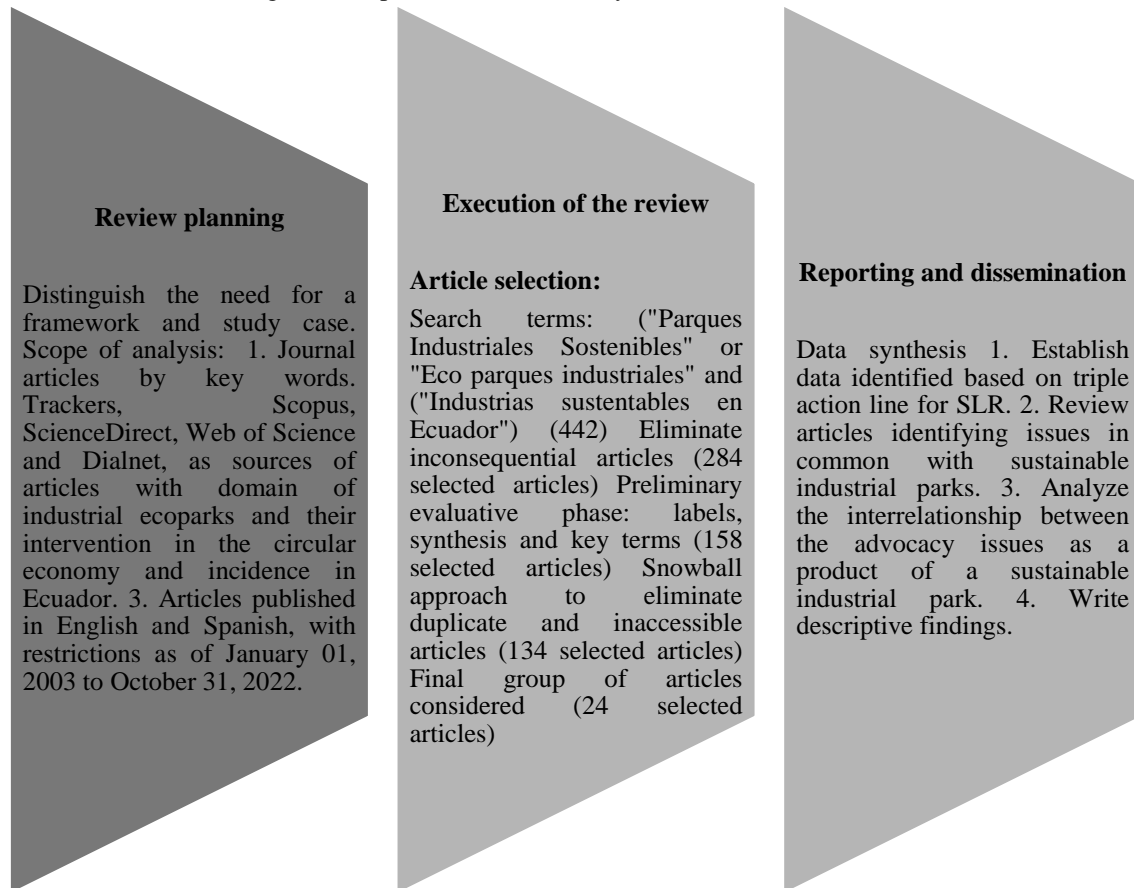
intercessory tool to reduce these impacts, creating collective and economic benefits. As a contribution to a sustainable industrial development, UNIDO presents a Guide to develop PAIS in eight Latin American countries that were part of a pilot test, among them: Argentina, Bolivia, Chile, Costa Rica, El Salvador, Guatemala, Paraguay and Panama, showing total willingness to work for the common welfare (ONUDI, 2017).

Latin America is already developing ideas emphasizing sustainability by anticipating market requests, offering structure and pre-existing conditions that facilitate client decision-making (Elabras-Veiga & Magrini, 2009; Morales et al., 2019; Vega-Quezada et al., 2017). However, it is complex to apply PaIS because of the need for synergies that have yet to take off, as well as the collective idea in which SD principles are the starting point, valuing environmental, collective, economic and political aspects of integrated decisions in interactive learning processes among social actors (Kurilova-Palisaitiene et al., 2018; Manavalan & Jayakrishna, 2019; Muyulema-Allaica & Ruiz-Puente, 2022).

## **METHODOLOGY**

Methodologically, the systematic literature review (SLR) approach adopted by different authors (Beltrami et al., 2021; Cruz-Ríos et al., 2022; Farias et al., 2019; Lee & Edmondson, 2017; Qureshi et al., 2020) was used. To ensure rigor throughout the process, this study adhered to the three widely accepted steps for a SLR comprising: planning, execution, and dissemination of analysis. Accordingly, key words were established to search the literature. To preserve the reliability of the data, the search was limited to peer-reviewed journal articles, excluding other types of articles, such as conference papers, book chapters, short surveys, editorial notes, among others (Figure 1). Relevant articles published in PaIS domain from January 01, 2003 to October 31, 2022 were considered. Relevant articles were found in the most prominent search engines, namely ScienceDirect, Web of Science and Dialnet. Finally, the forward snowball and backward snowball approach adopted by Ekhuemelo et al., (2019); Kirchherr & Charles, (2018) was used by eliminating duplicity and including every relevant document.

Figure 1. Triple line of action for systematic literature review.



Source: Prepared by the authors (2023)

The third line of action for the SLR made it possible to review and classify 24 articles of interest pertinent to the topic, describing figures, conceptualizations and congruencies among various authors. The researcher read the summary, results and discussion sections of each selected article in particular.

Table 1 shows the synthesis of the topics reviewed by the PaIS study intervention according to authors, tools, results obtained and opportunities for synergy.

Table 1. Intervention topics in PaIS

N°	Author	Tools	Results	Synergy opportunities
1	(Fouladi et al., 2021)	Optimization models.	Resource-efficient capturing trade-offs in total and environmental impact.	progressObtaining improvement with costresource efficiency, through optimization models.
2	(Andrago-Alobuela & Arroyo-Morocho, and EC. 2022a)	Checklist between I4.0	Identification of challenges and opportunities when applying I4.0 and CE as a means of transformation in Ecuador's industries.	Roadmap as a means of linear oftrans-formation to circulate in the industries of Ecuador.
3	(Torre-Marín, 2011)	IE tools methodologies.	Transformation of a linear model into a circular model.	Creation of a network of linked industries in IE methods.

4	(Yamane & Kaneko, 2022)	CSR indicators.	Integral participation of stakeholders.	Decision-making framed in an ethical-transparent CSR with stakeholders.
5	(Ayala del Pino, 2021)	CSR analytical framework.	Competitive advantages of companies in the market.	Corporate impacts on the environment, applying CSR approaches.
6	(Pache-Durán & Nevado-Gil, 2020)	Technique for analyzing responsible corporate practices.	Value generation for the entity and social stakeholders.	Manufacturing performance and increased corporate transparency.
7	(Garzón-Castrillon, 2020b)	Stakeholder checklist.	Behavior of companies with stakeholder involvement measured in financial terms.	Stakeholder impacts on the ED.
8	(Moreno-Prieto, 2015a)	Classification by areas of intervention according to stakeholders.	Leveraging vital areas to companies with CSR.	Optimal company performance in by taking advantage of areas of intervention according to the importance of stakeholders.
9	(Uusikartano et al., 2021)	Pragmatic evaluation of the role of public stakeholders.	Performance of public stakeholders in the PaIS by means of a stakeholder map.	Range of interaction between public stakeholders and PaIS.
10	(Rocha et al., 2021)	RESOLVE structure.	Acceptance of CE in the market.	Changes in the conventional linear model to a circular model through RESOLVE structure as acceptance of the CE in a PaIS.
11	(Fuentes-Barrera et al., 2021a)	Analytical Process.	Structural analysis of networks capable of interlinking companies that make up a PaIS.	Evolution of PaIS, through synergy networks between companies.
12	(Muyulema-Allaica, 2018)	Discursive collisions.	Elaboration of strategies for SD in Ecuador.	Intervention of the CE as the beginning of development in Ecuador.
13	(Luján, 2003)	Criteria of an EPI.	Association of companies familiar with the conceptualization of an EPI.	Participation of companies related to the concept of an EPI.
14	(Lavagnino et al., 2014)	Taxonomy of indicators in the IS.	Existence of synergies between companies.	Formation of sustainable enterprises through the synergy of IS.
15	(Santos-Navarro, 2021)	SD projects.	Strategic lines of action for the implementation of CE in Ecuador.	Creation of PaIS in Ecuador.
16	(Woldu, 2022)	Criteria and indicators for an EPI.	Identification of resilience indicators in an EPI.	Establishment of sustainability through indicator analysis.
17	(Bravo-Calle et al., 2021a)	Impact evaluation.	Analysis of environmental impacts by industries.	Sustainable industrial development as a response to the reduction of environmental impacts by industries.
18	(Sánchez-Trujillo et al., 2013a)	Taxonomy of indicators in CE.	Conservative industrial system.	Cyclic flow in CE with function in manufacturing processes, using a conservative industrial system.
19	(Loayza-Pérez & Silva-Meza, 2013a)	Focus group.	Incorporation of green strategies in companies as a means of reducing the environmental footprint.	Groups benefiting from the implementation of an EPI based on green strategies.
20	(Han et al., 2022)	Agent-based modeling (ABM)	Simulation with non-linear symbiosis networks between industries.	ABM with functional simulation in PaIS.
21	(Pavón et al., 2012)	ABM	Analysis of heterogeneous behavior in complex systems.	ABM integration in complex systems.

22	(Moya et al., 2022a)	ABM	Behavior of the energy field in Ecuador.	Analysis of manufacturing behavior through ABM in Ecuador.
23	(Demartini et al., 2022b)	Modeling approaches.	IS as the main entity of modeling performance.	Focus on computational models based on IS.
24	(Iglesias-Piña, 2021b)	Taxonomy of indicators in CE.	of SI as a model tool for a DS in EC.	SI as a transcendental source of change from linear to circular model.

Source: Prepared by the authors (2023)

## RESULTS AND DISCUSSION

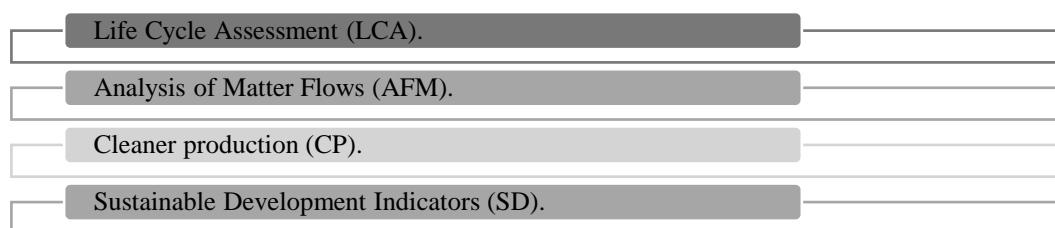
### Systematic Literature Review: Significance of PaIS

Industrial progress has been made possible through the use of natural resources by developing various systems that generate value-added products and services. One of the methods mentioned is the traditional linear system (take-make-use-dispose), in which natural resources are depleted and the waste products of this system are not used, resulting in an inefficient and environmentally costly method for companies (Fouladi et al., 2021).

Experts Andrago-Alobuela & Arroyo-Morocho (2022b) mention that the transition to emerging industries provides innovation of production models capable of integrating ecological practices such as: 1) the economic increase resulting from reducing production costs; 2) the generation of value as an innovative product of sustainable alternatives; and 3) invention as a proposal for change from the traditional model to the circular model based on new production models capable of reintegrating and reducing the volume of waste generated in production processes.

Figure 2 shows that, currently, companies are considering integrating the circular model (take-make-use-recycle) based on the tools and methodologies of IE, detailing that it is a multidisciplinary field that seeks to relate the industrial ecosystem with the natural one by working with industrial interrelationships, social and natural environments using fractions of industrial waste as raw material for another, completing the cycle of materials and achieving zero waste (Torre-Marín, 2011).

Figure 2. IE tools and methodologies.



Source: Prepared by the authors (2023)

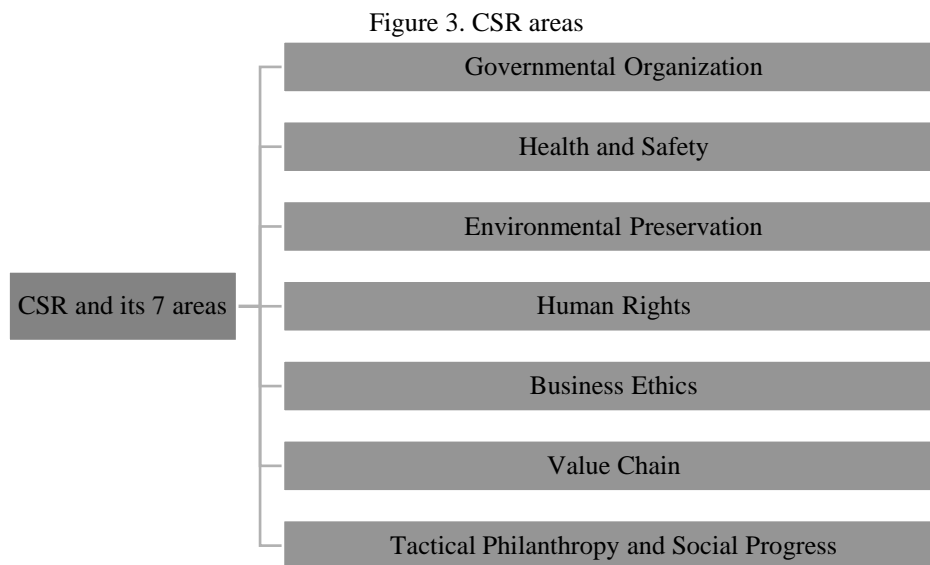


Consequently, the voluntary nature goes hand in hand with CSR, which, according to (Ayala del Pino, 2021), establishes that CSR has a common objective: "The behavior of the company must be consistent with the plans of responsibility beyond economic profit". In other words, CSR refers to the impact that companies have on the economic, social and environmental dimensions.

Accordingly Ayala del Pino (2021); Pache-Durán & Nevado-Gil (2020) also state that CSR is a methodology of comparative advantage aimed at companies and instruments that generate value for the institution and for stakeholders, also known as interest groups.

Stakeholders are analyzed as a fundamental part of the company because they play a leading role in the outcome of change due to the strategies that companies implement or incorporate in their management, setting organizational sustainability (Garzón-Castrillon, 2020a).

In Figure 3, it is described that CSR is immersed in 7 areas that oblige it to be deployed (Moreno-Prieto, 2015b), processed, moderated and reported on in a stakeholder-aware procedure. Among the areas are shown:



Source: Prepared by the authors (2023)

Experts Uusikartano et al., (2021) describe the involvement of public actors as an integrated set of policy instruments (creating opportunities and appropriate conditions) in order to actively orient current markets towards sustainability through increased collaboration between companies. In addition, they mention that the involvement of public actors develops

operational and support roles, financial, regulatory and political means, all of which intervene in industrial CE ecosystems that are closely related to the countries.

Globally, around 1.9 billion metric tons of solid waste are generated each year, creating environmental impacts and economic costs. In response to this and in view of an SD, the IE and the PAIS are looking for ways to address a more sustainable industrialization, ensuring that the purpose of industrial eco-parks is to achieve the cooperation of multiple plants through the exchange of resources, the integration of waste and the use of sustainable resources, i.e., to transform traditional linear systems (open loop) to closed/circular systems (closed loop) through the conviction of a common point: to reduce and reuse inputs for other processes (Torre-Marín, 2011).

Functioning that gives space to CE in relation to preserving the utility, economic and environmental value of materials as much as possible, either by extending their useful life or by adopting a closed loop of components in a product, i.e., fostering a better use of resources, reducing waste and pollution (Rocha et al., 2021).

Rocha et al., (2021) through case study research and interviews with experts, the Ellen MacArthur Foundation has identified a general set of six actions that companies and governments can take to transition to a circular economy (Tabla 2).

Table 2. RESOLVE Structure

Phase	Actions
<b>Regenerated</b>	Switching to renewable energies and materials.
	Recovery and restoration on ecosystem welfare.
	Reintegrate rescued biological resources back into the biosphere.
<b>Share</b>	Asset division.
	Exploitation of used material.
	Prolonging life through sustainability, stable design, modernization capacity, among others.
	Increased efficiency in product profitability.
<b>Optimize</b>	Eliminate waste in the supply chain.
	Take advantage of big data, mechanization, remote sensing, among others.
	Remanufacture items.
<b>Loop</b>	Tangible recycling.
	Anaerobic sewage.
	Extract biochemicals from organic waste.
<b>Virtualize</b>	Dematerialize directly and indirectly.
	Replace old with modern non-renewable tangibles.
<b>Exchange</b>	Intervention of new technologies (e.g., 3D printing).
	Choose a new product service (e.g., multimodal transport).

Source: Prepared by the authors (2023)

The authors Fuentes-Barrera et al., (2021b) mention that CE is promoted as a critical SD concept because it promotes among industries a change from a linear production model to

a circular flow model, where resources - products - renewable resources intervene as a solution to environmental impact and resource exploitation.

Emphasizing conceptualizations through the SLR of various articles, the concepts of the following authors are presented:

The conceptualization of EPI was formalized and expanded internationally in 1993 with studies carried out by the "Indigo Development" team, Dalhousie University in Scotland and Cornell University in the United States through the United States Environmental Protection Agency (USEPA) in agreement and under treaty with Research Triangle Institute and Indigo where it is also established that an EPI is a community of industrial plants located in the same geographical area developing economic and environmental improvements under clean production parameters (Loayza-Pérez & Silva-Meza, 2013a).

The researchers Loayza-Pérez & Silva-Meza, (2013b) also add that it is possible to delimit groups of IPEs: the first is made up of conglomerates and entities with interlinked processes but which in turn carry out different industrial activities, as opposed to the second group made up of entities that carry out the same activities. This type of analysis makes it possible to study groups of benefits obtained with the implementation of EPIs: 1) Creation of added value and 2) The organization of industrial areas with the improvement of environmental quality.

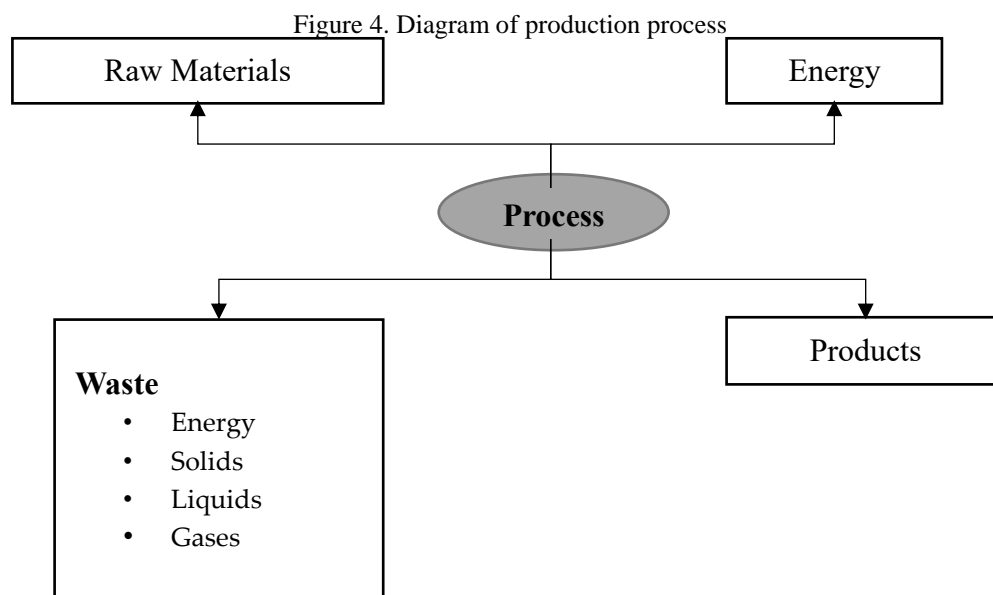
While Woldu, (2022) expresses that EPIs are the group of entities installed in a common property that interrelate with each other through collaboration by efficiently sharing their resources obtaining gains in economy, environmental quality and impartial improvement of human resources, for each entity and local collectivity.

The authors Bravo-Calle et al., (2021b) define PaIS as the collectivity of industrial plants that interrelate in cooperation as they share resources with the aim of improving their production, social and environmental means.

Researchers Sánchez-Trujillo et al., (2013b) describe the meaning of a PAIS derives from adaptations with ecological beginnings in manufacturing techniques that incorporate ideologies of IE, Clean Production and value addition in Waste Management, giving rise to an industrial system that conserves natural and economic resources, allowing the improvement of production, efficiency, public image, providing opportunities and profit exploitation for industries. In other words, a PaIS is a corporation of manufacturing negotiations and services that seek collective benefits more than their own.

An EPI represents a better version of an industrial cluster with various entities interacting with each other through the exchange of waste/resources or energy in each case in order to achieve optimal work, and offers a complex adaptive system (CAS) involving multiple sectors and non-linear interactive behaviors. The case of Symbiosis in Kalundborg Denmark who since 1970 has inspired for 40 years around the world the intervention of an EPI that offers considerable changes in economic and environmental benefits through in-industrial symbiosis is exposed (Han et al., 2022).

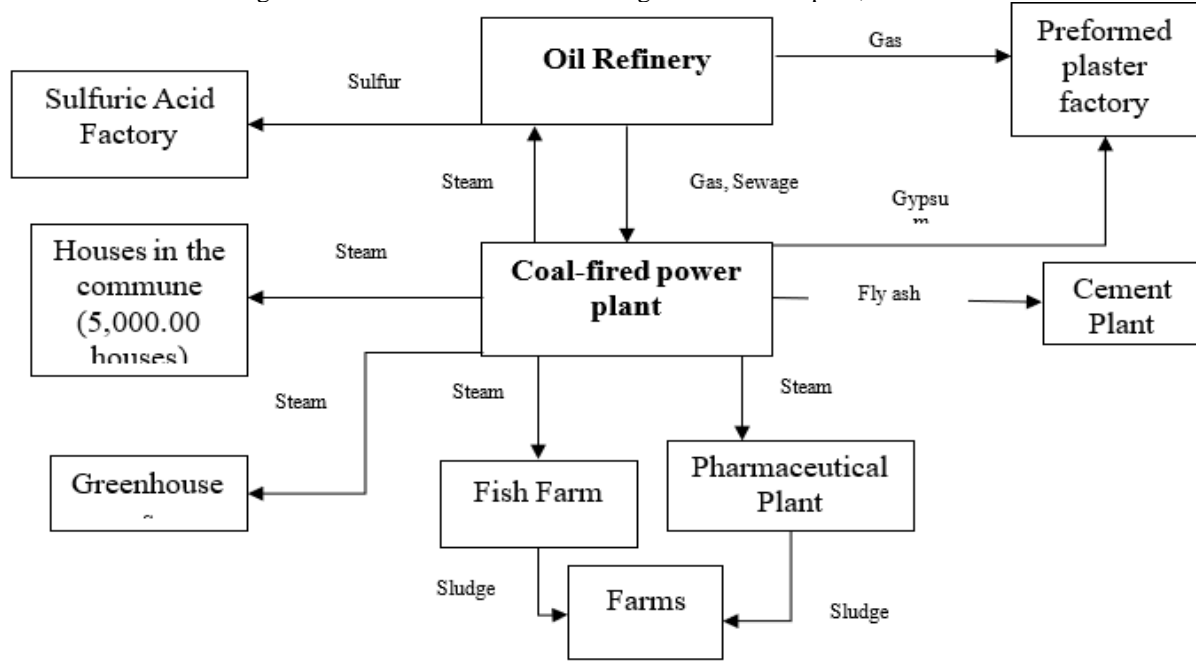
In Figure 4, it is necessary to highlight the analysis of Luján, (2003) for mentioning that an IPE is established within the same industrial district with entities that maintain productive transformations linked by supplies, consumption of raw materials, services required and waste generated.



Source: Prepared by the authors (2023)

The author Luján, (2003) in the research: "Eco-industrial parks, an SD Option for the Regional Productive Sector" mentions the case of the Kalundborg eco-industrial park in Denmark, which, although being a metropolis with only 20,000.00 residents developed a sustainable industrial park with companies from the same region (Figure 5).

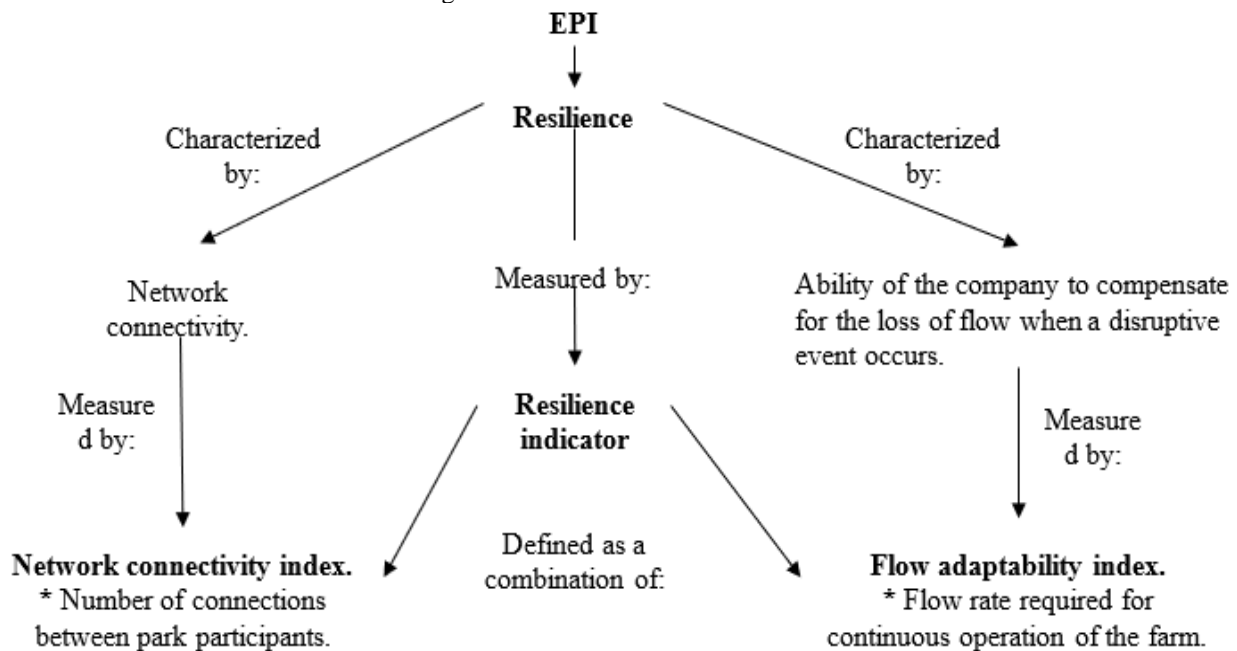
Figure 5. Schematic of the Kalundborg eco-industrial park, Denmark.



Source: Prepared by the authors (2023)

And it highlights that industries use resilience to significantly increase their productivity by being part of an EPI, embracing new concepts on IE, highlighting their presence with a better image in society and achieving SD in the sector. While Woldu, (2022) illustrates the main characteristics of resilience used in an EPI and the structure of the resilience indicator proposed to measure it (Figure 6).

Figure 6. Resilience used in an EPI



Source: Prepared by the authors (2023)

However, as previously mentioned, PISs function as long as company waste is considered raw material for others; this process is called industrial symbiosis. However, Lavagnino et al., (2014) mention that symbiosis is a biological phenomenon considered to be characteristic of macroevolutionary development, because includes a diversity of phenomena, including community life and the proximity of organisms among a variety of species.

The authors Fuentes-Barrera et al., (2021b) detail that EPIs emerge as a tool for the development of sustainability based on a non-linear model, seeking industrial symbiosis networks that last over time and overcome the challenges between economic compensation and environmental performance. Furthermore, it points out that assessing such networks allows for the improvement of organizational interfaces through collaborative interactions between industries in an EPI.

In order to understand the networks that are formed between industries, one of the most recent developments in technology is the computational tool: ABM, which allows to analyze and design the behavior between agents in order to test and validate the results of emerging models in complex systems (Pavón et al., 2012). At the same time an ABM is able to illustrate complexities demanding manufacturing centered on heterogenous characteristics of industries (agents), generating diverse analysis of relationship variables, in this case symbiosis networks. Advantageously, this computational tool achieves the reception of stakeholders' group practices and impact mechanisms by critical influencing factors (Moya et al., 2022a).

To apply an ABM between industry networks, a common factor called industrial symbiosis (IS) is needed, where two or more entities cooperate in making sustainable business decisions and share common resources (Demartini et al., 2022b). The conformation of the IS, is due to the collaboration, cohesion and synergy existing between the variety of economic activities that are located in geographically proximate territories, making possible the existence and growth of a PaIS that functions with established entities that share resources achieving economic and social improvements (Iglesias-Piña, 2021b).

The ABM highlights the potential IS relationships to facilitate a modeling of interrelationships between agents through an inductive or bottom-up approach to simulate CAS dynamics, involves the heterogeneous behaviors of plants, companies or entities involved and evaluates the impact on the overall performance within the EPI (Han et al., 2022).

### **Congruent Point Among Authors**

In the respective investigations and by means of a cross-check selection, it is evident that the self-researchers refer to the ISPA as a community of companies, entities or industrial plants located in the same geographical area (Iglesias-Piña, 2021a; Loayza-Pérez & Silva-Meza, 2013b; Luján, 2003; Sánchez-Trujillo et al., 2013b; Woldu, 2022).

The authors Woldu, (2022); Luján, (2003) agree that the PaIS are the group of entities installed in a common property, i.e., in the same industrial area. While among the conceptualizations Bravo-Calle et al., (2021b); Luján, (2003) determined that the function between the entities that make up a PAIS is fostered by the interrelationship between them, in other words, it is the relationship between resources, raw materials consumed, services required, products and waste generated.

Researchers Loayza-Pérez & Silva-Meza, (2013b) describe SIPs as the community of industrial plants capable of developing economic and environmental improvements under clean production parameters, a criterion shared by (Sánchez-Trujillo et al., 2013b), who mention industries as corporations of manufacturing and service businesses that seek collective benefits rather than their own.

With respect to the ABM Moya et al., (2022b); Demartini et al., (2022a), they conclude that the use of a computer model presents better opportunities to study complex systems with the intervention of agents, since these, being heterogeneous and independent, show indicators such as symbiotic utilization, eco-efficiency, resource manufacturing and environmental impact.

An ABM allows interpreting the flexibility of a PaIS by simulating the individual behaviors and interrelationships within the system presented by heterogeneous and autonomous agents who have their own rules of behavior, agreeing that this model needs a network of industrial symbiosis to be executed (Han et al., 2022; Iglesias-Piña, 2021a; Moya et al., 2022b).

### **Possibility of Applying PaIS in Ecuador**

In Ecuador, EI and CE are part of the development of basic industries for generating inputs for other industries in the country, and the change of paradigms stands out as an incipient result in the increase of efficiency, due to the use of the environment, controlling elements such as the cascading consumption of resources, the category of waste, greater commitment of producers, IS and the assumption of unprecedented in-come models (Muyulema-Allaica, 2018).

The study conducted by INEC, based on the generalized results, shows that 98% of companies in Ecuador do not have environmental management systems or international certifications, according to the survey on Private Expenditure and Investment in Environmental Protection (INEC, 2010).

The following results are presented by division of the survey:

The primary sector had the highest proportion of environmental spending and investment, registering 61.4% focusing on purchasing equipment and assemblies that reduce wastewater pollution. A total of 33.7% of companies invest in environmental protection by acquiring equipment and systems that reduce polluting emissions, 19.5% in energy consumption and 18.5% in water conservation. With a low proportion of business capital, there are equipment and assemblies that reduce waste generation by 9.3% and 1.4% in noise and vibrations (INEC, 2010).

A decade later, the same institute has made a new tabulation taking as a reference the values calculated between 2019 and 2020 regarding environmental economic information in large and medium-sized companies in the country. The report shows that in 2020, 31.6% of the entities have certain environmental permits, increasing by 7.0% compared to 2019. Regarding current expenditures on environmental protection and resource management activities, it shows that companies invested capital by 37.2% in 2019, while in the following year there was an increase of 40.6% in financing. The primary sector being the main diligent sector with 94.0%. A pressing data to analyze is the deficit of companies that do not have registration as a generator of hazardous waste, since only 15.7% of the entities have this register (INEC, 2022).

To understand the intervention of CE in Ecuador (Muyulema-Allaica, 2018) emphasizes that as long as the country remains in a globe isolated from the economic framework, referring to the habitual economy, it will make it impossible to understand the companies in general.

According to Muyulema-Allaica & Ruiz-Puente, (2022), in Ecuador there are organizations based on principles and values, some of which are sustainable and participatory with a view to evolution, adapting to changes linked to current legal regulations, the health situation, and political and economic conditions. It also mentions that entrepreneurial competences are dependent on more initiatives with voluntary character, that drive their goals to the satisfaction of collective needs, with respect to nature and ethical-co-transparent practice.

The idea of a PaIS is contemplated in Ecuador because it has a National Development Plan in force which includes strategies that seek to encourage environmentally responsible production and consumption, as long as their bases are the CE and bioeconomy, promoting



recycling and combating programmed absence. Mention should be made of the White Paper on Circular Economy in Ecuador, which sets out strategic guidelines for the implementation of CE in Ecuador (Santos-Navarro, 2021).

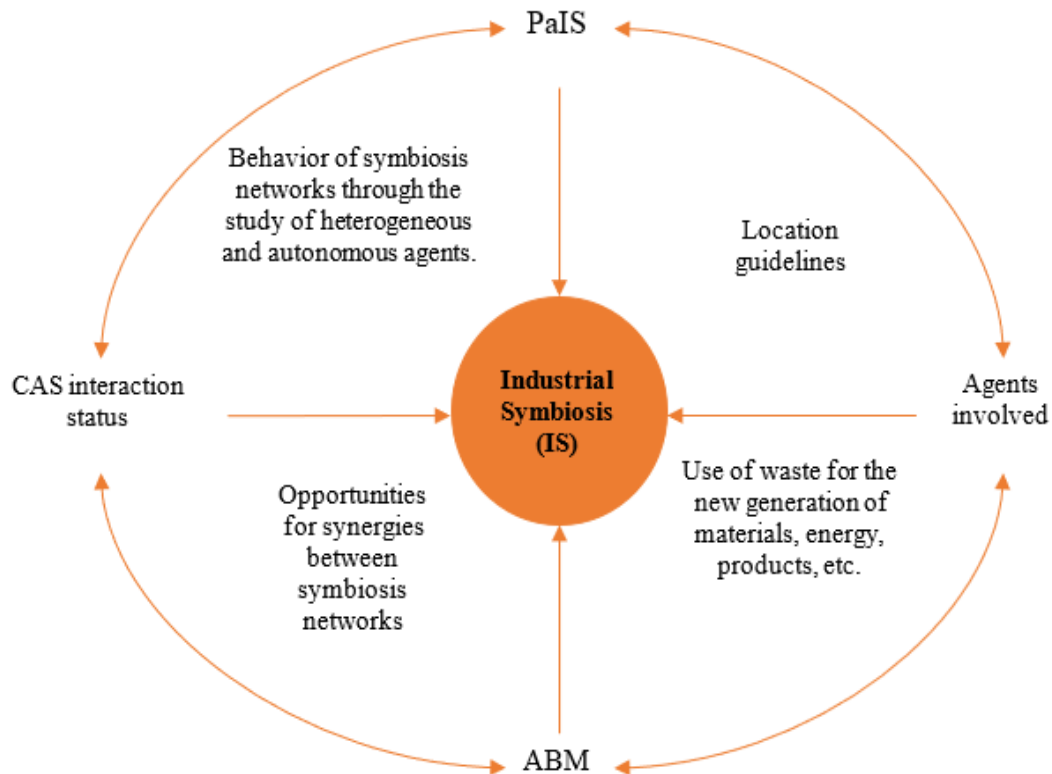
Five projects are included in the White Paper as a contribution to the SD commitment:

1. Closing of the water cycle and use of nutrients.
2. Reduction of food losses and waste with application of bioeconomy principles.
3. Capacity building for each province depending on its productive matrix with a view to innovation based on circular business models and including public corporate responsibility.
4. Implementation of industrial symbiosis at national and provincial level.
5. Acceptance of zero waste models for Municipal Decentralized Autonomous Governments (MDAG).

However, for Andrago-Alobuela & Arroyo-Morocho, (2022b) Ecuador still does not have a state regime that allows a leap to a new industrial revolution, because the country must consider rethinking the production paradigms, considering the factors for and against, but this does not mean that the initiatives that the country has for the conservation of the environment are discarded, since in the Ecuadorian Constitution of 2008, in articles 71 and 72 three rights are mentioned: 1) integral consideration of its presence, 2) conservation and renovation of its transcendental cycles, structure, actions and evolutionary processes; and, 3) legality to rehabilitation, indicating that in the country there are signs of change towards an SD in friendship with environmental conservation.

Based on the reality studied in Ecuador and with the previous analyses regarding the intervention of the PaIS, Figure 7 presents a model of integration to the CE through the IS that is coupled both to the objectivity of Ecuadorian manufacturing and to the application in manufacturing with a sustainable mentality that wishes to belong to the group of change that the CE proposes within one of its many tools, in response to the suggestion of the research Framework proposal for the design of lean circular production systems based on case studies to propose guidelines that propagate an existing synergy between Lean and CE by means of IS (Muyulema-Allaica & Ruiz-Puente, 2022).

Figure 7. Model of integration to the CE by means of SI



Source: Prepared by the authors (2023)

## DISCUSSION OF RESULTS

As a result of the RSL, the research shows that Kalundborg in Denmark has demonstrated to the world for more than 40 years the positive change generated by the application of PaIS. In Ecuador there was evidence of a lack of environmental management and international accreditations in 98% of companies, that mining companies invest 64.1% in environmental investment, while other companies invest up to 33.7% in the purchase of equipment and systems to reduce polluting emissions, what is alarming is the energy consumption and water conservation that do not exceed 20% of investment demonstrating an instability of urgent attention for these industries. For 2020, 12.4% of the companies already have an environmental license and the investment in current expenses in environmental protection and natural resource management activities increased by 9.2% compared to 2019. These changes show slight progress in terms of environmental concerns, however, the situation of hazardous waste in the country is critical due to the fact that 84.3% of companies do not have records of waste generation. It is also noted that Ecuador does not have statistics and indicators to consolidate and critically synthesize the existing knowledge on some of the critical aspects of the development and operation of PaIS; however, a model of integration to the CE through the IS, is presented, which is analyzed positively as a mechanism of interconnection through

networks between manufacturing companies that seek to exchange their waste by implementing computational tools that offer real behavior in ABM simulations that demonstrate the interactions between industries.

## CONCLUSIONS

The SLR revealed that a PaIS is a set of industries, establishments or industrial zones established in the same geographical area that interrelate with each other, they are born as a tool for SD and are able to function in a non-linear model with symbiosis networks.

The objective of the PaIS is to contribute to change in a sustainable manner, its functionality is based on receiving what for many companies is waste, for others it can be raw material (industrial symbiosis process). It allows for an industrial system that conserves natural and economic resources, which leads to improved production, efficiency and public image, facilitating opportunities for industries and the exploitation of profits.

With the experience acquired in the SLR, it is concluded that Ecuador is apt to implement an IS-based PaIS through an ABM as a start to CE as long as the country changes its position of conventional economy, supporting as a State the transformation required by the industries for the development and conservation of the eco-system.

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