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**LEONARDO DE QUEIROZ BRAGA CAVALCANTE**

# A THEORETICAL FRAMEWORK FOR THE MANAGEMENT OF ECO-INDUSTRIAL DEVELOPMENT

**FORTALEZA**
**2012**

LEONARDO DE QUEIROZ BRAGA CAVALCANTE

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Master's thesis presented to the Graduate Program in Administration and Controllership of the Faculty of Economics, Administration, Actuarial Science, and Accounting of the Federal University of Ceara as a partial requirement to obtain the master's degree in Administration and Controllership. Area of concentration: Production Management.

Advisor: Prof. José Carlos Lázaro da Silva Filho, PhD.

Co-advisor: Prof. Raymond P. Côté, MSc.

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To God.

To my spirit guides.

To my mother, Lúcia.

To my friends, Ivone and Valerie.

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“Sejam, meus irmãos, artífices sempre de construções coletivas, que ganham mais em beleza, substância, originalidade, qualidade.” (CÂMARA, 2011).

## ABSTRACT

An alternative for organizations to drive industrial systems toward a more sustainable path is to stimulate the process of eco-industrial development (EID). By participating in an eco-industrial network, firms achieve cost reduction, revenue enhancement, or business expansion while generating positive externalities for the surrounding communities and natural ecosystems. Although EID is a strategic initiative for the sustainability-profitability trade-off, the researchers from the field of industrial ecology (IE) have been working without a theoretical connection with the fields of organization studies and contemporary management theories. Due to such factors, IE has deficiencies concerning strategic management, which restrict the incorporation of the approach of EID into managerial practices. Whenever EID has been tangential to the corporate level strategy, eco-industrial networking has not been supported by prerequisite investments, such as management, measurement, and accountability systems, as well as skilled staff for overall synergism. As a result, the implementation of industrial symbioses is isolated, fragmented, and uncoordinated. Moreover, it is deficient in quantitative standards for the evaluation of sustainability performance. All those features create various problems during eco-industrial networking, such as technological, economic, informational, cultural, organizational, and regulatory ones. As a result, most renowned EID initiatives are far from achieving all of their sustainability goals. In view of the lack of a management approach to industrial ecology and its negative effects on industrial symbiosis, the main objective of this thesis is to introduce a theoretical framework for the management of eco-industrial development. The theoretical framework for the management of industrial ecosystems provides knowledge that managers can later appropriate and reapply as part of their discourse and management approach. Through this theoretical framework, it is supposed that the key concepts of EID, such as community, cooperation, interaction, and efficiency, would become achievable goals for managers of industrial ecosystems. Furthermore, the proposed scheme broadens industrial ecology's techno-environmental approach based on a mechanistic viewpoint by incorporating industrial symbiosis tools into organizational issues such as strategy, structure, leadership, culture, and environmental management.

**Keywords**: biomimicry; eco-industrial development; industrial ecology; industrial ecosystem; management approach.

## RESUMO

Uma alternativa para as organizações direcionarem os sistemas industriais para um caminho mais sustentável é estimular o processo de desenvolvimento ecoindustrial (EID). Ao participar de uma rede ecoindustrial, as empresas obtêm redução de custos, aumento de receita ou expansão de negócios, ao mesmo tempo em que geram externalidades positivas para a comunidade circundante e os ecossistemas naturais. Embora o EID seja uma iniciativa estratégica para o trade-off sustentabilidade-rentabilidade, os pesquisadores da área de ecologia industrial (EI) têm trabalhado sem uma conexão teórica com os campos dos estudos organizacionais e das teorias contemporâneas de gestão. Devido a tais fatores, a EI apresenta deficiências na gestão estratégica, que restringem a incorporação da abordagem do EID nas práticas gerenciais. Sempre que a EID foi tangencial à estratégia de nível corporativo, a rede ecoindustrial não foi apoiada por investimentos de pré-requisito, como sistemas de gestão, medição e responsabilidade, bem como pessoal qualificado para sinergia geral. Como resultado, a implementação de simbioses industriais é isolada, fragmentada e descoordenada. Além disso, é deficiente em padrões quantitativos para avaliação do desempenho da sustentabilidade. Todas essas características criam vários problemas durante as redes eco-industriais, como tecnológicos, econômicos, informacionais, culturais, organizacionais e regulatórios. Como resultado, a maioria das iniciativas globais de EID estão longe de atingir todas as suas metas de sustentabilidade. Tendo em conta a falta de uma abordagem de gestão da ecologia industrial e os seus efeitos negativos na simbiose industrial, o principal objectivo desta tese é apresentar um quadro teórico para a gestão do desenvolvimento eco-industrial. O arcabouço teórico para a gestão de ecossistemas industriais fornece conhecimento que os gestores podem posteriormente se apropriar e reaplicar como parte de seu discurso e abordagem de gestão. Por meio desse referencial teórico, supõe-se que os conceitos-chave da EID, como comunidade, cooperação, interação e eficiência, se tornariam metas alcançáveis para os gestores de ecossistemas industriais. Além disso, o esquema proposto amplia a abordagem tecnoambiental da ecologia industrial com base em um ponto de vista mecanicista, incorporando ferramentas de simbiose industrial em questões organizacionais como estratégia, estrutura, liderança, cultura e gestão ambiental.



**Palavras-chave**: biomimética; eco-industrial desenvolvimento; ecologia industrial; ecossistema industrial; abordagem de gestão.

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## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| BIE | Benevides Industrial Ecosystem |
| BIU | Benevides Industrial Unit |
| CAEPIM | Cooperativa Agrícola dos Empreendedores Populares de Igarape-Miri |
| CAMTA | Cooperativa Agrícola Mista de Tomé-Açu |
| CAMTAUA | Cooperativa Mista Agroextrativa de Santo Antonio do Taua |
| CART | Cooperativa Agrícola Resistência de Cametá |
| CEPLAC | Comissão Executiva do Plano da Lavoura Cacaueira |
| COAPROCOR | Cooperativa Agroindustrial de Produtores de Corumbataí do Sul |
| COFRUTA | Cooperativa de Fruticultores de Abaetetuba |
| COOMAR | Cooperativa Mista de Agricultores |
| COOPCAO | Cooperativa de Produtores de Cacau Orgânicos |
| COPAVAM | Cooperativa dos Agricultores do Vale do Amanhecer |
| COPOAM | Cooperativa de Produtos Orgânicos da Amazônia |
| COPOBOM | Cooperativa de Produtores de Cacau Orgânico do Bom Jardim |
| COPOPS | Cooperativa de Produtos Orgânicos de Perpétuo Socorro |
| COPOTRAM | Cooperativa de Produtores Orgânicos da Transamazônica |
| COPOXIM | Cooperativa de Produtores de Cacau Orgânico do Bom Jardim |
| CSR | Corporate Social Responsibility |
| EE | Ecosystem Ecology |
| EID | Eco-Industrial Development |
| EMATERCE | Empresa de Assistência Técnica e Extensão Rural |
| EMBRAPA | Empresa Brasileira de Pesquisa Agropecuária |
| FASE | Federação de Órgãos para Assistência Social e Educacional |
| GRA | Geo-Economic Region of the Amazon |
| IE | Industrial Ecology |
| IS | Industrial Symbiosis |
| MA | Millennium Ecosystem Assessment |
| MC | Model of Commitment |
| MEID | Management of Eco-Industrial Development |
| OEID | Office of Eco-Industrial Development |
| OERM | Office of Eco-Relationships Management |
| OMTIB | Objectives, Metrics, Targets, Initiatives and Budget |

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## 1 INTRODUCTION

The interaction of businesses with ecosystems and the use of ecosystem services by industries for fulfilling supply chains are some of the key factors in environmental change (BOONS; ROOME, 2000; LIFSET; GRAEDEL, 2002; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005b). They have contributed to the degradation of two-thirds of the worldwide ecosystem services (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005b). The underlying cause of those factors is the business decision-making process based on the principles of technocentrism, anthropocentrism, and neoclassical economics which makes the overall product life cycle the source of most pollution and depletion of natural resources (BAUMANN; BOONS; BRAGD, 2002; EGRI; PINFIELD, 2001; GLADWIN; KENNELY; KRAUSE, 1995; HOPWOOD; MELLOR; O'BRIEN, 2005; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005b; PIGOSSO *et al.*, 2010; PURSER; PARK; MONTUORI, 1995). For this reason, all products cause some kind of negative impact on the environment during their life cycle, from the extraction of raw materials to their manufacture, use, and disposal (LIFSET; GRAEDEL, 2002; PIGOSSO *et al.*, 2010).

According to the Millennium Ecosystem Assessment (MA) (2005b), environmental degradation will affect business and industry over the next 50 years through three principal factors: the increase of operating costs, the increase of external pressure from stakeholders, and the emergence of new business opportunities for sustainable technologies. For helping businesses and industries deal with such challenges and opportunities, the Millennium Ecosystem Assessment (2005b) recommends six actions for managers:

a) analysis of ecosystem services throughout the business value chain for planning sustainable corporate strategies;
b) product lifecycle and supply chain management integration for interacting multiple demands on ecosystem services;
c) research, development, and demonstration (RD&D) for increasing efficiency of ecosystem service use or ecosystem service supply;
d) partnerships with other companies, government agencies, and civil society organizations to accelerate corporate learning about ecosystems and ecosystem services, leverage resources and skills, and build trust with important stakeholders;
e) business decision-making based on forecasts about customer preferences for sustainably supplied services, new regulations, competitor strategies, investor

demands for sustainable business models, and the establishment of market mechanisms;

f) disclosure on the impact of operations on ecosystem services to key stakeholders for building trust, enhancing reputation, and building brand association with ecosystem conservation.

These MA actions are comparable to methods and approaches used in the field of industrial ecology (IE) to reduce environmental impacts. Their fundamental goal of reconciling economic systems with the natural environment is conceptually similar to the purpose of IE. Industrial ecology, in particular, seeks to balance conservation needs with growing human demand for natural resources through the restructuring of manufacturing processes to make them compatible with the way natural ecosystems function in terms of material and energy flows (BOONS; HOWARD-GRENVILLE, 2009; CÔTÉ, 1997; 1998; 1999; FROSCH; GALLOPOULOS, 1989; INTERNATIONAL SOCIETY FOR INDUSTRIAL ECOLOGY, 2012a; ISENMANN, 2003; JENSEN; BASSON; LEACH, 2011; LIFSET; GRAEDEL, 2002; WRIGHT *et al*., 2009).

It is important to note that IE methods and approaches are capable of performing MA actions in order to effectively accomplish a balance between industrial and ecological systems: MA actions 1 and 6 can be implemented through material and energy flow studies and life-cycle assessment; MA actions 2 and 5 achieve their goals through product-oriented environmental policy and extended producer responsibility; and MA action 3 is comparable to design for the environment, eco-efficiency, dematerialization, and decarbonization. Considering these capabilities, the following conclusion can be drawn: the field of industrial ecology can play a significant role in addressing sustainability imperatives.

According to Ashton (2008; 2009), Baas and Boons (2004), Bain *et al*. (2010), Boons and Spekkink (2012), Chertow, Ashton, and Espinosa (2008), Costa and Ferrão (2010), Costa, Massard, and Agarwal (2010), Deutz and Gibbs (2008), Deutz and Lyons (2008), Geng, Haight and Zhu (2007), Guo and Cui (2010), Hewes and Lyons (2008), Jacobsen (2006), Kokossis and Yang (2009), Korhonen and Snakin (2005), Lambert and Boons (2002), Lyons (2007), Martin (2010), Mirata and Emtairah (2005), Posch (2010), and Sokka *et al*. (2010), industrial symbiosis (IS) and eco-industrial development (EID), which is comparable to MA Action 4, are the key factors for accelerating the transition towards a sustainable industrial system. This hypothesis is supported by Bennet and Bennet (2004), Boons, Spekkink, and Mouzakitis (2011), Chertow (2000; 2007), Cohen-Rosenthal (2003), and Côté and Cohen-Rosenthal (1998). Moreover, the International Society for Industrial Ecology (2012b) states that industrial symbiosis and eco-industrial development are responsible for putting industrial ecology theories into practice [1].

Therefore, it is reasonable to assume that the success of all other industrial ecology initiatives and their corresponding MA actions depends heavily on industrial symbiosis. Due to this reason, businesses, non-governmental organizations, and government agencies that seek to transform industrial systems into sustainable ones in order to improve resource efficiency must promote eco-industrial development. Consequently, society, the economy, and the natural environment will develop relationships that are mutually beneficial (CHERTOW, 2007; COHEN-ROSENTHAL, 2000; 2003).

Although EID is strategic for the field of industrial ecology and has relevance for the reduction of poverty, improvement of human well-being, and protection of the environment (CHERTOW, 2007; COHEN-ROSENTHAL, 2000; 2003), industrial ecologists have not yet proposed a management theory of eco-industrial development, especially one that addresses industrial symbiosis (BAAS; BOONS, 2004; EILERING; VERMEULEN, 2004; HASLER, 2005; KORHONEN, 2005; SINDING, 2000). In the following sections, it will be examined what factors contribute to the dearth of management discussions in industrial ecology.

## 1.1 The phenomenon of eco-industrial development

The introduction of industrial ecology as a field of scientific study in 1989, through an article titled "Strategies for Manufacturing," written by Robert Frosch and Nicholas E. Gallopoulos and published in the popular science journal Scientific American, brought a new model for business transformation. In order to reconnect industry and nature, industrial ecologists suggest that firms should be designed according to organizational principles found in biological ecosystems (EHRENFELD, 2007; GRAEDEL; ALLENBY, 1995; HESS, 2010; ISENMANN, 2003; LIFSET; GRAEDEL, 2002; MCMANUS; GIBBS, 2008; WRIGHT, 2007).

Thereafter, "the metaphor of a natural ecosystem as a basis for the normative goal related to economic activities and thus contributing to sustainability or decreasing ecological impact" has been one of the core elements of industrial ecology (BOONS; HOWARD-GRENVILLE, 2009, p. 5). This original normative goal is based on a principle that establishes

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[1] For the International Society for Industrial Ecology, the core topical areas of industrial ecology currently acknowledged are: Industrial Symbiosis and Eco-Industrial Development; Socio-Economic Metabolism; Sustainable Urban Systems; Organizing Sustainable Consumption and Production; Environmentally Extended Input Output; and Life Cycle Sustainability Assessment.

a linkage between IE and the ecological sciences. To reinforce this perspective, Wright (2007) affirms that industry systems are simply another type of ecosystem, just like aquatic, terrestrial, and wetland ecosystems, which depend on natural resources. In accordance with this principle, Jensen, Basson, and Leach (2011, p. 680) argue that "industrial ecology is the ecology of industry and should be studied as such."

In addition to an ecosystem approach, the analysis of material and energy flows and a systems perspective are also essential components of IE (BOONS; HOWARD-GRENVILLE, 2009; GRAEDEL; ALLENBY, 1995; LIFSET; GRAEDEL, 2002). All of them are heavily influenced by ecosystem ecology (EE) concepts (LIFSET; GRAEDEL, 2002). Industrial ecologists borrowed from EE the emphasis on the interactions between biotic systems, including humans as an essential component, and the physical environment on which they depend (CHAPIN; MATSON; MOONEY, 2002). Additionally, other concepts from EE have contributed to the development of IE, including nutrient cycling, decomposition, trophic interactions, food chains, metabolism, succession, and symbiosis, as evidenced by Côté (1997; 1998; 1999), Côté and Hall (1995), Côté and Smolenaars (1997), Ehrenfeld and Gertler (1997), Jensen, Basson, and Leach (2011), Wright (2007), and Wright *et al*. (2009).

As stated in the traditional normative goal of IE based on an ecosystem approach, the model for configuring organizational design should be loop-closing, a particular property of type III ecosystems that enables dynamic and harmonious relations with the biosphere (CÔTÉ, 1997; 1998; 1999; CÔTÉ; HALL, 1995; CÔTÉ; SMOLENAARS, 1997; EHRENFELD, 2007; GRAEDEL; ALLENBY, 1995; HESS, 2010; ISENMANN, 2003; LIFSET; GRAEDEL, 2002; MCMANUS; GIBBS, 2008). The strong emphasis in industrial ecology on loop-closing is due to a study conducted by Graedel and Allenby (1995). The authors have measured the degree to which ecosystems depend on external inputs (energy and materials) and on the release of wastes to an external environment (LIFSET; GRAEDEL, 2002). Then, using a continuum of linearity in resource flows, they defined three types of ecosystems. Graedel and Allenby (1995) have observed that type III ecosystems have the greatest degree of cycling and the least reliance on external resources and sinks. Once the efficient cycling of resources is due to the closed material cycles of type III ecosystems, they are considered a model for configuring organizational design for industrial systems at many scales (LIFSET; GRAEDEL, 2002).

A business organization[2] should carry out an eco-industrial development program, using a top-down or bottom-up approach[3], to operationalize the imitation of organizational properties of a type III ecosystem at the company level (EILERING; VERMEULEN, 2004). During the execution of an eco-industrial development program, several processes are implemented, such as industrial metabolism, industrial symbiosis, material chains and webs, flexible manufacturing networks, and ecological design (CÔTÉ; COHEN-ROSENTHAL, 1998). One of the most essential activities is industrial symbiosis, the formation of a cluster through the connection of all business organizations involved directly or indirectly in the same value chain and located in the same geographical space. Industrial ecologists have come up with this type of integration, in which companies share information and business processes and revalue their waste as resources for each other.

The successful completion of eco-industrial development is the establishment of a sustainable business network, also referred to as an “industrial ecosystem,” whose organizational behavior generates beneficial relationships between organizations and the local community as well as improvements in social, economic, and environmental performance. Theoretically, an industrial ecosystem as a model of a sustainable business network would provide the means to achieve profit-driven corporate social responsibility. In turn, this will ensure the preservation of ecosystem services that sustain the industrial ecosystem and its associated businesses. As one can see, the process of eco-industrial development has expanded the way organizations are structured and run, which can be considered an advancement in management theory.

However, industrial ecologists still cope with industrial ecosystems from a techno-environmental perspective, as explained in Sections 1.2 and 1.3. Industrial ecology has been a field of systematic study on principles, techniques, methods, processes, means, and instruments for environmental management applied especially by environmental professionals at the level of industrial ecosystem operations. Due to this approach, industrial ecologists do not take into account the integration of environmental management with strategic management issues. Moreover, industrial ecologists’ environmental management systems have largely established strategies, objectives, metrics, and initiatives that emphasize only the reduction of environmental impacts while ignoring social and economic aspects. As a result of the adoption

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[2] In accordance with Cohen-Rosenthal (2003), the term “business organization” is approached in this text as “enterprise,” “industrial park,” or “regional network.”
[3] As stated by Eilering and Vermeulen (2004), the top-down approach is the eco-industrial development program ruled by the government. Through a bottom-up approach, the eco-industrial development program is initiated by the companies.

of the techno-environmental approach by industrial ecologists, Section 1.4 demonstrates that the field of IE lacks a management system for eco-industrial development, its most important branch, in conformity with Boons, Spekkink, and Mouzakitis (2011), Chertow (2000; 2007), Cohen-Rosenthal (2003), Côté and Cohen-Rosenthal (1998), and Isenmann (2003).

## 1.2 The techno-environmental approach to an industrial ecosystem

To understand the reason industrial ecologists focus on a techno-environmental perspective restricted to the domain of operations, it is necessary to reflect on the nature, methods, and limits of the knowledge produced by the field of industrial ecology, especially on the relationship established between industrial ecology and its research object[4]. First, it is necessary to consider that a fundamental point of view was adopted during the early stages of industrial ecology's development: the ecological system as a model for organizational thinking (HESS, 2010; ISENMANN, 2003; MCMANUS; GIBBS, 2008). As a result, industrial ecologists attempted to replicate the process of generating scientific knowledge in ecology (WRIGHT *et al*., 2009).

As well as the primary focus of ecology being the analysis of the natural mechanisms and functional processes that maintain the structure and services of ecosystems (for example, ecosystem metabolism), industrial ecologists developed frameworks for analyzing techno-environmental factors (namely, industrial metabolism) that could assist businesses in achieving sustainability. Such frameworks disregard management theories, despite the fact that an industrial ecosystem is fundamentally a business organization, and do not align techno-environmental factors with business strategy. Korhonen (2005) and Sinding (2000) say that management issues were not taken into account because industrial ecologists put too much weight on the fact that ecosystems at the industrial scale could organize themselves.

Industrial ecology, which is based on the direct interaction of production with its relatively close ecosystem components, has been influenced by the ecological metaphor (WRIGHT *et al*., 2009). This means that the primary techno-environmental factors considered by industrial ecologists are restricted to the boundaries of the value chain. Industrial ecologists

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[4] The research object is the focus of attention or area of concentration. The focus of industrial ecology is "the use of technology to reduce environmental impacts and reconcile human development with environmental stewardship while recognising the importance of socioeconomic factors in achieving these goals. Industrial ecology studies often quantify the use and cycling of materials and energy in society and their exchanges (extraction and emissions) with nature. Such analyses focus on different levels and scales, from eco-industrial parks and cities to nations and the global economy" (INTERNATIONAL SOCIETY FOR INDUSTRIAL ECOLOGY, 2012a).

strictly adhere to the industrial metabolism viewpoint, which investigates the uses and flows of materials and energy in the production of goods. The life cycle assessment is an essential instrument in industrial ecology for determining the flow of materials and energy. This tool follows the same principles used by ecologists to determine how biomass, nutrient cycling, and trophic dynamics operate in ecosystems.

Through the application of life cycle assessment, industrial ecologists strive to comprehend how environmental impacts might be mitigated throughout the product's lifecycle. In general, industrial ecology scientists construct theoretical models that seek to explain how to reduce environmental impact based on material and energy flow evaluations in production systems. Such theories contribute to the advancement of knowledge in various subfields of industrial ecology, which include technological change, dematerialization and decarbonization, design for the environment, extended producer responsibility, eco-industrial development, product-oriented environmental policy, and eco-efficiency.

The techno-environmental approach has limited the scope of industrial ecology to environmental management theories, empirical research, and knowledge application at the operational level of an industrial ecosystem. This trend in knowledge production and application in the field of industrial ecology has resulted in the development of a number of environmental management tools, such as cradle-to-cradle, dematerialization, design for environment, design for disassembly, green engineering, green purchasing, green shipping, industrial materials recycling, lean manufacturing, and water treatment.

Despite the fact that these tools have improved environmental performance, their effects are restricted to the operational level and diminish when they are isolated from other organizational perspectives, such as financial, customer/stakeholder, and learning. Taking into account Kaplan and Norton's (2008) strategy management system, it seems reasonable to say that operational gains made through environmental management that are not tied to corporate strategy would not be likely to last, even if they bring many benefits to a business company.

Moreover, the techno-environmental approach to the industrial ecosystem has encouraged the adoption of eco-industrial development measuring methods that consider environmental performance measures. These indicators only look at the impact of production on natural ecosystems. In light of Kaplan and Norton's (2008) finding that the success of a business organization is contingent on cause-and-effect interactions across financial, stakeholder, operational, and knowledge levels, such an eco-industrial development evaluation system can be viewed as insufficient.

### 1.3 The mechanistic viewpoint of an industrial ecosystem

Industrial ecologists express their points of view on an industrial ecosystem explicitly in industrial "food web" diagrams. Ideally, as a model for an industrial ecosystem, cyclical industrial "food web" diagrams are highly desirable due to their efficient use of resources and capital. This objective can be enhanced by emulating the structure of type III ecosystems. However, the industrial "food web" diagrams usually designed by industrial ecologists do not match the structural principles of type III ecosystems, which are characterized by constant change, dynamic equilibrium, flow, self-organization, systemic wisdom, attractors, chaos, complexity, emergent properties, dialectical properties, and paradox (BENNET; BENNET, 2004; KAY *et al*., 1999; 2000; MORGAN, 1996).

In general, industrial "food web" diagrams disregard the functionality of a type III ecosystem, which is characterized by multidimensional interactions with other ecosystems and major natural support structures. Most of the time, industrial "food web" diagrams depict a self-sufficient and mechanistic business network that does not account for other social, economic, or environmental factors. As in Morgan's (1996) and Spiegelman's (2003) mechanistic viewpoints of organizations, the fundamental concepts underlying industrial "food web" diagrams are efficiency, waste, maintenance, order, inputs and outputs, standardization, production, measurement and control, and design.

The mechanistic viewpoint of industrial "food web" diagrams implies a misunderstanding of the dependence of business organizations on the existence of a natural ecosystem and a healthy society that provides education, health care, equal opportunity, and strong regulatory standards, as suggested by the Millennium Ecosystem Assessment (2005b). Ehrenfeld (2007) asserts that industrial ecologists are incapable of addressing the three components of sustainability due to their insufficient understanding of the relationship between the natural and social worlds and industrial ecosystems.

### 1.4 The lack of management theories in industrial ecology

As clarified by Eilering and Vermeulen (2004), Korhonen (2005), Salonen (2010), and Sinding (2000), industrial ecology lacks management theories due to its emphasis on the techno-environmental approach based on a mechanistic perspective of industrial ecosystems. Incorporating industrial symbiosis and eco-industrial development into strategic management is hampered by the lack of a management theory for industrial ecosystems. Since eco-industrial development has been peripheral at the corporate strategic level, where, according to Kaplan and Norton (2008), leadership can mobilize change, industrial symbioses or corporate alliances[5] are not supported by prerequisite investments, such as management, measurement, and accountability systems, as well as trained personnel, for overall synergy.

As a result, the implementation of industrial symbiosis within industrial ecosystems is isolated, fragmented, uncoordinated, and deficient in quantitative standards for the evaluation of sustainability performance, as indicated by Eilering and Vermeulen (2004). During the establishment of industrial symbioses, these deficiencies generate various technological, economic, informational, cultural, organizational, and regulatory issues (HEERES *et al*., 2004). Under these conditions, the majority of industrial ecosystems are far from achieving all of their sustainability-related goals[6].

To avoid problems in industrial symbiosis caused by the mechanistic orientation of the techno-environmental approach, businesses, non-governmental organizations, and government agencies must integrate industrial ecosystem strategies into the corporate strategies of business organizations (EILERING; VERMEULEN, 2004). In this context, the industrial ecosystem, as an organizational model, is comprised of several organizational units interacting continuously under a single industrial ecosystem strategy aimed toward eco-industrial development in order to capture economies of scale and scope. This vision of an industrial ecosystem is, as expected, a difficult undertaking, given that industrial ecosystems typically consist of multiple business units with varying purposes, some of which are unsustainable. It leads us to believe that aligning all organizations with the same strategy is necessary for incorporating industrial ecosystem strategy into corporate strategy.

Appropriately, the alignment within an industrial ecosystem should rely on a mechanism that manages industrial symbioses[7] or synergies among system members (BAAS; BOONS, 2004; EILERING; VERMEULEN, 2004), thereby putting the industrial ecosystem strategy into action. Based on Kaplan and Norton's (2006; 2010) research on corporate alliances, it is reasonable to assume that the alignment between industrial ecosystem strategy and corporate alliance strategies will not be effective in the absence of such a management

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[5] A corporate alliance for sustainability or industrial symbiosis requires organizations and skilled employees to execute sustainable business processes that deliver customer and stakeholder value, which drives shareholder outcomes. By means of such outcomes, eco-industrial development should be measured.

[6] Objectives of an industrial ecosystem: (i) to increase shareholder wealth, (ii) to satisfy the needs of customers and stakeholders, (iii) to create extraordinary value for civil society, and (iv) to protect human health and safety and the natural environment.

[7] Industrial symbiosis refers to corporate alliances or synergies for sustainability that are managed by an alignment system.

mechanism. Therefore, the chance to create ecosystemic value through eco-industrial development may be missed.

## 1.5 Research questions and objectives

Through empirical research, Eilering and Vermeulen (2004), Korhonen (2005), Salonen (2010), and Sinding (2000) show that the field of industrial ecology has not developed a managerial approach to industrial ecosystems based on the characteristic of self-organization of ecosystems. Despite these theoretical flaws in management theory, Atitude (2011), Behera *et al.* (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al.* (2011), and Yuan *et al.* (2010) provide examples of effective EID initiatives. These initiatives implement administrative procedures that may constitute a fundamental industrial ecosystem management approach. This set of processes has most likely contributed to the success and durability of these EID initiatives.

In addition to not offering a management approach, industrial ecology does not provide any tools for determining if a particular management strategy for an industrial ecosystem has achieved eco-industrial development. This circumstance renders it unreliable for industrial ecologists to simultaneously assess whether an industrial ecosystem addressed the three components of sustainability and contributed to the harmonious relationship between its members and the natural and social worlds. Such a circumstance calls for a theoretical framework for a more comprehensive and deep analysis of the EID management strategy. Industrial ecologists must therefore create a logical structure or theoretical framework for the study of industrial ecosystem management in order to solve the limited EID assessment of an industrial ecosystem.

On the basis of the aforementioned assumptions, the arguments of Eilering and Vermeulen (2004), Korhonen (2005), Salonen (2010), and Sinding (2000), as well as the phenomenon, the significance, and the limitations of the study, the following thesis question was formulated: *Which theoretical framework could industrial ecology use to cope with problems in the management approach to eco-industrial development?* This question can be answered by accomplishing the following objectives.

### *1.5.1 General objective*

In view of the lack of a management approach to the industrial ecosystem due to the focus on the techno-environmental approach based on the mechanistic viewpoint of the industrial ecosystem, the main objective of this thesis is *to formulate a theoretical framework for the management of eco-industrial development (MEID).*

### *1.5.2 Specific objectives*

g) to identify a priori concepts and variables relevant for the management of eco-industrial development;
h) to study a case according to these a priori concepts and variables for measuring constructs and verifying construct relationships;
i) to construct a theoretical framework that explains the relationships between those concepts and variables on eco-industrial development management.

## 1.6 Relevance of the study

Industrial ecology is the field of study that has the power to deal with sustainability at the business level (ALLENBY, 1998; EHRENFELD, 2007). IE rests on an international network of scholars who are located at the most important worldwide universities and is supported by the International Society for Industrial Ecology, the Journal of Industrial Ecology, the Journal of Cleaner Production, and the United States Business Council for Sustainable Development. Despite its relevance for competitive advantage and sustainable development, as stated by Esty and Porter (1998), the advancement of the field of industrial ecology in Brazil is still significantly small. Because of this, this thesis also aims at contributing to the production and dissemination of knowledge on IE in Brazil and integrating the Federal University of Ceara into the international network of scholars in the field of industrial ecology.

Through the proposed theoretical framework for the management of eco-industrial development, it is supposed that the key concepts of EID presented by Côté and Cohen-Rosenthal (1998), such as community, cooperation, interaction, and efficiency, would become achievable goals for managers of industrial ecosystems. Furthermore, the theoretical framework deals with the relationships of firms with the surrounding society and environment. As a result, it broadens industrial ecology's techno-environmental approach based on the mechanistic viewpoint by incorporating industrial symbiosis tools into organizational issues such as strategy, structure, leadership, culture, and environmental management.

This thesis was feasible due to the researcher's integration into the School for Resource and Environmental Studies (SRES) at Dalhousie University, a renowned institution for research on sustainability in Canada. Moreover, the researcher was supervised by Professor Raymond P. Côté, a leading expert on industrial ecology. His papers, books, lectures, seminars, and consulting services have been exerting a great influence on the progress of the field of industrial ecology. Since the field of industrial ecology was created, Professor Raymond P. Côté has been promoting it around the world through the Journal of Industrial Ecology, the Journal of Cleaner Production, and the Eco-Efficiency Centre at Dalhousie University.

# 2 METHODOLOGY

In view of the lack of a management approach to eco-industrial development and its negative effects on measurement, assessment, evaluation, the main objective of this thesis is to introduce a theoretical framework to guide the management of industrial ecosystems towards sustainability. This framework explains how to manage the incorporation of the concepts of eco-industrial development into the corporate-level strategies of business organizations pertaining to an industrial ecosystem. In doing so, it describes a kind of management process[8] for an industrial ecosystem that translates the EID concepts into action.

Introducing this management method to EID managers was crucial to the development of the suggested framework. It was the central objective around which the current research was organized. To accomplish this, the researcher deliberately studied the management of an industrial ecosystem. An important objective was to identify a management process for an industrial ecosystem as a series of evolutionary sequences of activities that occur in time and place, changing or sometimes remaining unchanged in response to the circumstance or context. It allowed the researcher to determine how and why eco-industrial development management evolves as conditions change.

The researcher adopted a qualitative approach to address this process-oriented objective. Corroborating Leech and Onwuegbuzie (2007; 2008; 2011), a qualitative study helped answer questions regarding the how and why of the EID management process. In addition, based on Denzin and Lincoln (2008), the researcher used a qualitative approach because it allowed him to interpret the management EID phenomenon in terms of the meanings business managers attributed to it. Taking into account Leech and Onwuegbuzie's (2007; 2008; 2011) explanations of qualitative research design, case study research was selected as the most effective method for examining the main construct of interest to this thesis as it manifests in a specific group of companies. In terms of the application of the case study, the current research has clarified EID issues that were intrinsic to a business group, going beyond a descriptive study. This case study required not only the development of concepts but also their integration into a logical framework in order to provide actionable guidelines for managing EID.

Eisenhardt's (1989) eight-step procedure for constructing theory from case study research was used to develop the proposed theoretical framework for the management of industrial ecosystems in an appropriate manner. The development of the theoretical framework involved

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[8] Management process is a process of planning and controlling the performance or execution of any type of activity.

writing about processes that were precisely identified, conceptually elaborated, and logically interconnected with other concepts. In order to maintain theoretical flexibility, EID-related theories and hypotheses were not considered. To improve the grounding of construct measures, the researcher merely selected 59 a priori constructs from the literature. Thus, they were distributed across six macro variables: (I) the office of eco-industrial development; (II) the development of an industrial ecosystem strategy; (III) alignment management; (IV) industrial symbiosis management; (V) accountability management; and (VI) system adaptation management.

As recommended by Eisenhardt (1989), the researcher employed a theoretical sampling and focused efforts on a theoretically useful case, an industrial ecosystem fostered by Natura Cosméticos S.A., a cosmetic firm based on biodiversity products that figured as number two on the 2012 Global 100 List[9]. This industrial ecosystem has special characteristics due to its location near suppliers of natural essences in the Amazon Rainforest, in the northern region of Brazil.

To strengthen the foundation of the theoretical framework through triangulation of evidence, as recommended by Eisenhardt (1989), multiple data gathering techniques have been employed by the researcher: semi-structured interviews with Natura's managers and suppliers; document gathering including text, videos, and pictures; and non-participant observation. The researcher applied a triangulation of data analysis in accordance with Leech and Onwuegbuzie's (2007; 2008; 2011) recommendations for increasing the rigor and trustworthiness of qualitative data findings. To fully comprehend the phenomenon of EID management in the industrial ecosystem fostered by Natura in Benevides, Pará, more than one type of data analysis technique was utilized.

During the initial phase of data analysis, the preliminary theoretical framework was generated using "constant comparison analysis"[10] based on the techniques of "open coding"[11] and "axial coding."[12] Eisenhardt (1989), Leech and Onwuegbuzie (2007; 2008; 2011), and

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[9] The Global 100 is an annual project initiated by Corporate Knights Inc., the company for clean capitalism. The Global 100 is the most extensive data-driven corporate sustainability assessment in existence, and inclusion is limited to a select group of the top 100 large-cap companies in the world. Launched in 2005, the annual Global 100 is announced each year during the World Economic Forum in Davos and published at http://www.global100.org/.

[10] Constant comparative analysis is a process developed by Glaser and Strauss (1967) and utilized in the theory-building process, in which raw data excerpts are sorted into constructs based on their attributes, and then those constructs are arranged in a logical order to form a new theory.

[11] "Open coding" is a typical starting stage in the analysis of qualitative research and is frequently employed in the theory-building process (GLASER; STRAUSS, 1967; STRAUSS; CORBIN, 2008). At this point in the current study, the researcher has already gathered qualitative data, including interview transcripts and documents. Using open coding, he split his data into separate parts and gave each one a "code," which is a rough construct.

[12] "Axial coding" is the second phase of coding in the theory-building process, after open coding (GLASER; STRAUSS, 1967; STRAUSS; CORBIN, 2008). In contrast to open coding, which divides data into isolated codes (rough constructs), axial coding establishes connections between codes. The codes generated by open coding are

Strauss and Corbin (2008) attest that such analysis techniques of qualitative data improve construct definition, validity, and measureability. After coding the data collected by means of open coding and axial coding to gather evidence in support of a priori constructs, the researcher employed "selective coding,"[13] the process of searching for evidence of the reasons underlying relationships between constructs, in order to establish internal validity. The researcher then compared the preliminary theoretical framework with existing literature published between 2007 and 2012 on industrial symbiosis and eco-industrial development. Eisenhardt (1989) argues that this method of data analysis increases internal validity, enhances construct definitions and generalizations, and raises the theoretical level.

On the basis of a framework for evaluating the quality of qualitative research developed by Spencer *et al.* (2004), Johnston (2006) recognizes transparency as one of the most important attributes of good research. Transparency in this context refers to an honest explanation of how the research was conducted, including a detailed description of the sampling, data collection, and analysis processes, as well as an honest discussion of the strengths and weaknesses of the study (JOHNSTON, 2006). In order to achieve a high level of transparency in this study, the researcher employed three strategies: (i) the use of NVivo 10[14] throughout the entire analysis process; (ii) the detailed account of how the proposed framework was developed; and (iii) the discussion of the relative strengths and weaknesses of the proposed framework for guiding the management process of all types of industrial ecosystems.

NVivo 10, a qualitative data analysis (QDA) program[15], has assisted the complete analysis process through the offering of techniques such as "coding," "memos," "queries,"

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arranged using axial coding. In this study, the researcher employed axial coding to classify his codes and underlying data based on their correlations with a priori constructs. Following axial coding, the researcher was equipped with a list of categories and subcategories supported by a simplified set of supplementary codes.

[13] "Selective coding" is the last phase of the theory-building process, during which a researcher links all of her categories to a fundamental category. Thus, one constructs a cohesive theory around your findings (GLASER; STRAUSS, 1967; STRAUSS; CORBIN, 2008). Selective coding was the culmination of this study and linked the categories the researcher derived from his qualitative data in prior coding cycles, such as axial coding. In selective coding, the core category was "the management process of eco-industrial development." Ultimately, this core category reflects the essential idea of the present research.

[14] NVivo 10 provides a high level of transparency within the current research because it is possible for supervisors and examiners to view not only the data but also what the researcher has done with that data and to track the processes involved in the whole research journey (JOHNSTON, 2006).

[15] In order to analyze data by himself through qualitative computing, the researcher attended a NVivo 9 workshop offered by Raewyn Bassett, assistant professor and PhD candidate at the Faculty of Health Professions at Dalhousie University. It was held at the School for Resource and Environmental Studies (SRES) at Dalhousie University on two Tuesdays: February 15, 2011, and March 8, 2011, from 9am to 4pm. It was a two-day NVivo 9 workshop with instruction in the coding and analysis of transcripts, photos, video, documents, and survey data. On Day One, basic functions in the software were taught, and more advanced functions such as the query tool, models, and cases—as well as how to use traditional data analysis methods (e.g., thematic analysis, grounded theory) in the software—were taught on Day Two.

"models," and "visualizations." "Coding" was a way of gathering all the references (sentences and images) from a source (transcripts, documents, videos, pictures, or literature) and assigning them to a specific variable (construct) and, consequently, a macro variable (macro construct). The researcher coded all types of sources and brought the references together in a single node, which represents a variable in a macro variable. Coding helped the researcher find patterns and relationships in the research material and come up with new ideas.

"Memos" are a type of word processor that allowed the researcher to record ideas, insights, interpretations, and a growing understanding of the subject matter. They provided a way to keep the analysis separate from, but linked to, the material analyzed. "Queries" provided a flexible way to gather and explore subsets of data. The researcher has created queries to find and analyze words or phrases in sources and nodes. The objective was to find specific words or those that occur most frequently. In addition, the researcher has asked questions about the data and found items that are associated in a particular way with other items. "Models" and "visualizations" were ways of visually exploring and presenting the data. The researcher used models and techniques of visualization, such as charts, cluster analysis, tree maps, and graphs, to: set out and review initial ideas about the management process of eco-industrial development; represent visually two types of relationships, macro variable vs. macro variable, and macro variable vs. variables; and identify emerging patterns, theories, and explanations.

The next sections explain the creation of the proposed theoretical framework for the management of industrial ecosystems. In Section 2.1, the relationship between the researcher's mind and reality is discussed. The principles that the researcher used to discover "the management of eco-industrial development" are outlined. Also described are his reasoning processes and how he came to know MEID. Section 2.2 describes specifically the process employed by the researcher for building the proposed theoretical framework from a case study on an eco-industrial development initiative.

## 2.1 Epistemological approach in research

Initially, the researcher determined the fundamental features of an industrial ecosystem. Based on the most recent definition of a social institution by Abercrombie, Hill, and Turner (2006)[16], he understood an industrial ecosystem to be an economic institution that

[16] According to Abercrombie, Hill, and Turner (2006, p. 108), "social institution" refers to "social practices that are regularly and continuously repeated, are sanctioned and maintained by social norms, and have a major significance in the social structure." These authors highlight five key institutional complexes that are commonly

maintains society through the production, distribution, and consumption of goods and services. According to Popper's (1966, *apud* GIDDENS, 2000) social epistemology, the researcher acknowledged that the functioning of all industrial ecosystems must always be viewed as the consequence of human decisions, actions, and attitudes. He believed, in accordance with Popper (1966, *apud* GIDDENS, 2000), that industrial ecosystems are the result of transactions between individuals and can be analyzed as such at the strategic conduct level. On the basis of this, it was decided that an industrial ecosystem is an economic institution created by the actions of its constituent individuals. For this reason, the researcher has prioritized the decisions, actions, and attitudes of industrial ecosystem managers in the present study.

Using Strauss and Corbin's (2008) explanation of "actions of individuals"[17] as a theoretical reference, the researcher assumed that the actions of industrial ecosystem managers constitute the action process known as "the management of eco-industrial development." In conformity with Strauss and Corbin (2008), he recognized that this action process could be broken down into sub-processes, which consist of the individual tactics, strategies, and routines that comprise the MEID. The researcher decided to subdivide each of these subprocesses further into tactics for action and link each of them to its own properties, dimensions, strategies, and outcomes. In addition, he hypothesized that MEID could change or remain unchanged in response to alterations in environmental conditions.

The researcher recognized that the study of MEID as an action process could provide insight into the capacity of individuals, organizations, and groups to respond to and/or shape situations that impede their sustainability efforts. Based on Strauss and Corbin (2008), he thought MEID could demonstrate how individuals, organizations, and groups aligned or misaligned their actions with social norms in order to achieve eco-industrial development. The researcher considered it crucial to identify these social dynamics and potential outcomes within the industrial ecosystem investigated in this study.

Concerning the self-awareness of industrial ecosystem managers' actions, the researcher adhered to Giddens's (1979) explanation of the knowledgeability of social action. As said by Giddens (1979), the possession of knowledge of social action is always limited, and there

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recognized: (i) economic institutions; (ii) political institutions; (iii) stratification institutions; (iv) kinship institutions; and (v) cultural institutions.

[17] According to Strauss and Corbin (2008), the "actions of individuals" make up an "action process" that may be strategic, taken in response to problematic situations, or may be routine, performed almost without thinking. It can be ordered, continuous, sequential, or coordinated. In some cases, however, an "action process" can be a complete mess. The essential feature of all types of "action processes" is their evolving nature and their various forms, rhythms, and beats, all related to some goal (STRAUSS; CORBIN, 2008).

are two reasons for this: "Firstly, the spatial breadth of an agent's knowledge is circumscribed." "Secondly, an agent's knowledgeability is bounded by both the unacknowledged conditions of action, which include both unconscious and practical knowledge, and the unintended consequences of action" (GIDDENS, 1979, *apud* LOYAL, 2003, p. 31). On the basis of these principles, the researcher found it plausible that individuals participating in the management, operation, and maintenance of industrial ecosystems have limited understanding of the impact of their actions on eco-industrial development and sustainability.

As a consequence, the researcher decided to conform with Giddens's (1979) suggestion that social scientists uncover the limitations of an individual's cognitive grasp of social conduct. Following Giddens's (1979) recommendation, the researcher sought to elucidate the actions of eco-industrial development management not only in terms of their intentionality but also in terms of their beliefs, which were treated as (i) knowledge of social action and (ii) subsequent effects. To reach this goal, the researcher determined to form, based on Giddens (1979), a two-way dialogical relationship between himself and the informants, as opposed to a one-way technological relationship between the subject and an independent object, as in natural science.

Therefore, the researcher fully agreed with Giddens's (1984, *apud* LOYAL, 2003, p. 32) assertion that "the theories and the findings of the social sciences necessarily derive from lay discourse and become part of that discourse, thereby altering it irrevocably." Giddens (1984) calls this epistemological approach "double hermeneutic." Employed by the researcher in the current study, the "double hermeneutic" yielded management knowledge from managers' discourse, which managers can reapply as part of their discourse and management approach to eco-industrial development. Giddens (1984) highlights that individuals may think, make decisions, and utilize fresh knowledge to change their beliefs (and hence their practice). Consequently, managers of industrial ecosystems might modify their methods using the information and insights gained from this study.

Giddens (1984) points out two major consequences of adopting the "double hermeneutic." The first is the inability of social scientists to develop universal rules based on the limited knowledge of individuals and groups regarding social action. In light of this, the researcher acknowledged that the proposed theoretical framework for the management of an industrial ecosystem is inherently unstable. He recognized that industrial ecosystem managers have limited understanding (or beliefs) of their own decisions, actions, and attitudes toward eco-industrial development and sustainability.

The second major effect of the "double hermeneutic," as explained by Giddens (1984), is the obvious need for researchers to conduct a critical analysis of individuals' limited knowledge of social action. Giddens (1984) still affirms that if individuals appropriate and reapply the critical perspective in their discourse and actions, the analyzed society may undergo a transformation. By virtue of this explanation, the researcher hypothesized that his ideas, observations, and interpretations within the proposed framework would likely have practical implications for the management of an eco-industrial development initiative. He agreed, however, that improving practice may depend on managers of an industrial ecosystem using the proposed framework on their own to effect change and achieve sustainability.

## 2.2 The process of building the theoretical framework

This section describes the process of building the proposed theoretical framework for the management of industrial ecosystems using a case study on an eco-industrial development initiative fostered by Natura Cosméticos S.A. in Benevides, in the state of Pará, Brazil. According to Eisenhardt (1989), this method of developing theory from case study research is particularly appropriate for studies on new topic areas.

Given that industrial ecologists have not yet proposed a management theory for eco-industrial development, particularly one that copes with industrial symbiosis (BAAS; BOONS, 2004; EILERING; VERMEULEN, 2004; HASLER, 2005; KORHONEN, 2005; SINDING, 2000; VERMEULEN, 2004), Eisenhardt's (1989) method of building theory from case study research is appropriate in this thesis. The benefit provided by this type of research design is a novel, testable, and empirically valid theory due to its intimate connection with empirical reality (EISENHARDT, 1989). Table 1 summarizes how the researcher constructed the proposed theoretical framework in its entirety, and the sections that follow explain each stage of the research in detail.

Table 1 – The method of building theory from case study research

| **The process of building theory from case study research** | |
|---|---|
| ***Activity*** | ***Reason*** |
| **Step 1. Getting Started**<br>1.1 Definition of research question.<br>1.2 Specification of a-priori constructs.<br>1.3 Neither theory nor hypotheses. | 1.1 Focusing efforts.<br>1.2 Providing better grounding of construct measures.<br>1.3 Retaining theoretical flexibility. |
| **Step 2. Selecting Cases**<br>2.1 Specified population.<br>2.2 Theoretical sampling. | 2.1 Constraining extraneous variation and sharpens external validity.<br>2.2 Focusing efforts on theoretically useful cases. |

| | |
|---|---|
| **Step 3. Crafting Instruments and Protocols**<br>3.1 Multiple data collection methods. | 3.1 Strengthening grounding of theory by triangulation of evidence. |
| **Step 4. Entering the Field**<br>4.1 Overlap data collection and analysis.<br>4.2 Flexible and opportunistic data collection methods. | 4.1 Speeding analyses and revealing helpful adjustments to data collection.<br>4.2 Enabling investigators to take advantage of emergent themes and unique case features. |
| **Step 5. Analyzing Data**<br>5.1 Within-case analysis. | 5.1 Gaining familiarity with data and preliminary theory generation. |
| **Step 6. Shaping Hypotheses**<br>6.1 Iterative tabulation of evidence for each construct.<br>6.2 Search evidence for "why" behind relationships. | 6.1 Sharpening construct definition, validity, and measurability.<br>6.2 Building internal validity. |
| **Step 7. Enfolding Literature**<br>7.1 Comparison with similar literature. | 7.1 Sharpening generalizability, improving construct definition, and raising theoretical level. |
| **Step 8. Reaching Closure**<br>8.1 Theoretical saturation when possible. | 8.1 Ending process when marginal improvement becomes small. |

Source: Adapted by the author from Eisenhardt (1989, p. 2).

### *2.2.1 Getting started*

Taking into account the lack of a management approach to eco-industrial development, the researcher has defined a research question restricted to the management process for industrial ecosystems and focused on industrial symbiosis. Accordingly, the management process for an industrial ecosystem was the core category around which all research stages were carried out. This definition of the research question within one topic area of the field of industrial ecology permitted the investigator to specify the kind of industrial ecosystem to be approached and the type of data to be gathered. So, the researcher went into the chosen industrial ecosystem with a clear goal in mind and a plan for how to collect data.

Before entering the field, Eisenhardt (1989) advises researchers to formulate and possibly specify some potentially important "constructs," with some reference to existing literature. To do so, the researcher utilized Giddens' (1984) and Strauss and Corbin's (2008) epistemological approaches to assume an industrial ecosystem as a result of a management process. Based on the same authors, the researcher conceived of the management process for eco-industrial development as a series of evolutionary sequences of actions that occur in time and space, changing or sometimes remaining unchanged in response to the situation or context.

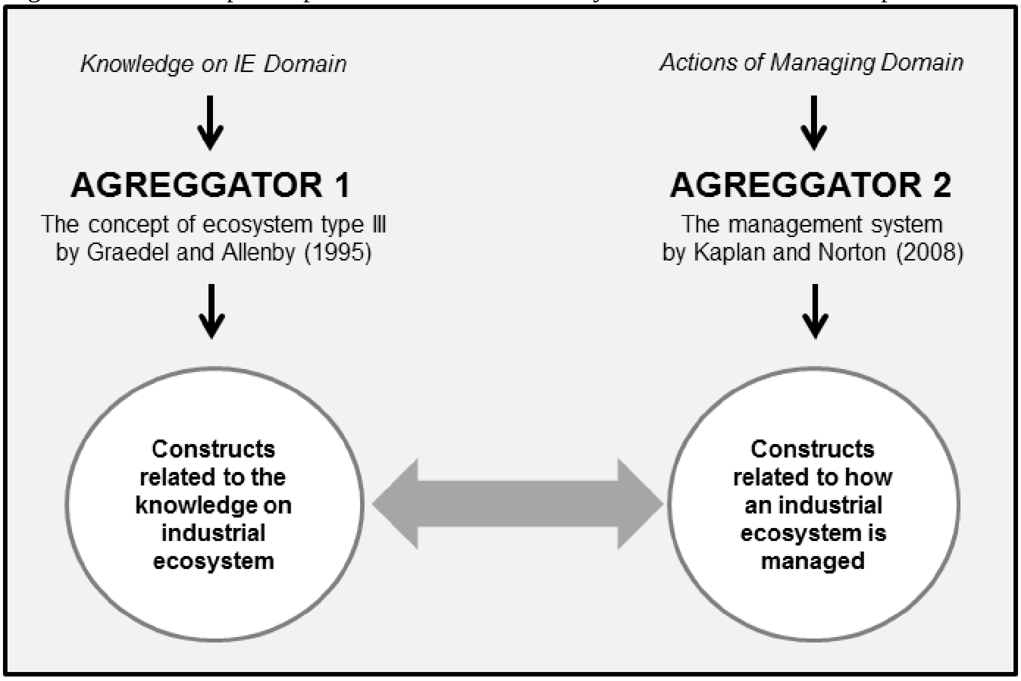
Still in accordance with Strauss and Corbin (2008), each action within the management process for eco-industrial development was treated by the researcher as a sub-process with its own properties, dimensions, strategies for action, and results.

In terms of analysis, the strategy was to consider the management process for eco-industrial development and its sub-processes as "constructs." To more accurately identify and measure constructs, the researcher used a priori specifications (EISENHARDT, 1989) by mens of the theoretical comparison method (STRAUSS; CORBIN, 2008). A series of constructs presumably related to the management process for eco-industrial development were extracted using that method from the literature on biomimicry (BENYUS, 1998), epistemology of industrial ecology (ISENMANN, 2003), eco-industrial development (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL), industrial symbiosis (CHERTOW, 2000; 2007), terrestrial ecology (CHAPIN; MATSON; MOONEY, 2002), consequences of ecosystem change for human well-being (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b), management system for linking strategy to operations (KAPLAN; NORTON, 2000; 2005; 2008), alignment (KAPLAN; NORTON, 2006), strategic alliances (KAPLAN; NORTON; RUGELSJOEN, 2010), shared value (PORTER; KRAMER, 2006; 2011) and social capital (PUTNAM, 1993).

The researcher employed the theoretical comparison method (STRAUSS; CORBIN, 2008) to establish "reference points" for the a priori definition of constructs (EISENHARDT, 1989). When selecting constructs from the cited literature, the researcher took the primary purpose of the present study into account. To arrange usefully selected constructs, the researcher determined two "aggregators" (FIGURE 1): (i) the beliefs about industrial ecosystems and their subsequent effects, both of which are treated here as industrial ecosystem knowledge; and (ii) the actions of managing industrial ecosystems. The researcher applied a theoretical comparison (STRAUSS; CORBIN, 2008) for linking the two construct aggregators respectively to two concepts whose properties, dimensions, strategies for action, and results could fill them: "the concept of ecosystem type III by Graedel and Allenby (1995)" and "the management system developed by Kaplan and Norton (2008)."

The tactic was to use the theoretical comparison method (STRAUSS; CORBIN, 2008) to establish both concepts as construct aggregators to guide a priori construct specification (EISENHARDT, 1989). As presented in Figure 1, the Aggregator 1 is the concept of ecosystem type III by Graedel and Allenby (1995) for assembling constructs related to the knowledge of industrial ecosystems. The Aggregator 2 is the management system developed by Kaplan and Norton (2008) that organizes constructs concerning how an industrial ecosystem is managed in order to achieve a high level of eco-industrial development.

Figure 1 – Overall a priori specification of constructs by means of theoretical comparison




Source: Adapted by the author

During the a priori specification of constructs (EISENHARDT, 1989) based on the method of theoretical comparison (STRAUSS; CORBIN, 2008), the researcher considered the ability of each construct from the mentioned literature to assist in clarifying both the meaning of an industrial ecosystem (Aggregator 1) and the management process of eco-industrial development (Aggregator 2). The previous specification of constructs yielded 59 constructs, which aided in the development of an "a priori framework" shown in Table 2. The a priori framework is a hypothetical description of the management process of eco-industrial development. The researcher deemed this early framework to be temporary and removed its components as soon as real data from the field research began to arrive.

Constructs 1 through 15 constitute the (I) description of an industrial ecosystem, which includes issues intrinsic to ecology and business and are related to Aggregator 1. Constructs 16–59 are associated with Aggregator 2 and organized into five macro constructs: (II) the development of an industrial ecosystem strategy; (III) alignment management; (IV) industrial symbiosis management; (V) accountability management; and (VI) system adaptation management. Despite the fact that a priori specification of constructs is not recommended for theory-building studies, Eisenhardt (1989) argues that such a method is useful for providing grounding for emergent theory. The researcher did not, however, consider a theory or hypothesis regarding the relationships between the chosen constructs. He meticulously selected a priori constructs as reference points without assuming relationships for the application of theoretical comparisons (STRAUSS; CORBIN, 2008) during the open coding and axial coding steps of data analysis.

Table 2 – A priori constructs on the management of eco-industrial development

| **I. Description of industrial ecosystem** |
|---|
| 1. *Primary components*: industrial organisms (producers, consumers and decomposers) inside an industrial ecosystem (CHAPIN; MATSON; MOONEY, 2002). |
| 2. *Secondary components*: adjacent society and environment of an industrial ecosystem (CHAPIN; MATSON; MOONEY, 2002). |
| 3. *Primary components' functions*: industrial ecosystem development, industrial metabolism, recycling, technological change, dematerialization and decarbonisation, industrial symbiosis (CHAPIN; MATSON; MOONEY, 2002). |
| 4. *Secondary components' functions*: the generation and regulation of the structure and services of the industrial ecosystem (CHAPIN; MATSON; MOONEY, 2002). |
| 5. *Industrial ecosystem development*: the process of making policies and operating practices that enhance the competitiveness of companies while simultaneously advancing the economic, social and environmental conditions in the communities in which it operates (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL). |
| 6. *Inspiring strategy for industrial ecosystem development*: ecosystem type III in nature (ISENMANN, 2003). |
| 7. *Theoretical background for industrial ecosystem development*: social capital theory (PUTNAM, 1993). |
| 8. *Operation of homeostasis in an industrial ecosystem*: investments in non-belonging components (society and environment) that generate and regulate the production cycles of the industrial ecosystem (CHAPIN; MATSON; MOONEY, 2002). |
| 9. *Industrial ecosystem goal*: human well-being and poverty reduction (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 10. *Reason for investing in human well-being and poverty reduction*: the conservation of ecosystem services (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 11. *Outcome of the conservation of ecosystem services*: eco-industrial balance and resilience (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 12. *Outcome of the destruction of ecosystem services*: costly operations and eco-industrial imbalance (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 13. *Mechanisms for cluster development*: reconception of products and markets and redefinition of productivity in the value chain (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 14. *Indirect mechanisms*: investments made by an industrial ecosystem in demographic, economic, socio-political, science and technology, and cultural and religious aspects. These contributions indirectly affect ecosystem services (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |

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|---|
| 15. *Direct mechanisms*: investments made by an industrial ecosystem in changes in local land use and cover; species introduction or removal; technology adaptation and use; external inputs; harvesting and resource consumption; climate change, natural, physical and biological drivers. These contributions directly affect ecosystem services (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| **II. Industrial ecosystem strategy** |
| 16. Clarification of mission, values and vision (KAPLAN; NORTON, 2000; 2005; 2008). |
| 17. Identification of the points of intersection between industrial ecosystem, society and natural ecosystem (PORTER; KRAMER, 2006; 2011). |
| 18. Choosing of social issues to address through industrial ecosystem (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; PORTER; KRAMER, 2006; 2011). |
| 19. Creation of a corporate social agenda: *(a) Responsive CSR, actions for good corporate citizen and for mitigating existing or anticipated adverse effects from business activities* (PORTER; KRAMER, 2006; 2011). |
| 20. Creation of a corporate social agenda: *(b) Strategic CSR, beyond best practices to pioneer innovations to benefit both society and a company's own competitiveness* (PORTER; KRAMER, 2006; 2011). |
| 21. Definition of the extent of industrial ecosystem, involving local community and natural ecosystem (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; MILLENNIUM ECOSYSTEM ASSESSMENT, 2005a; 2005b; PORTER; KRAMER, 2006; 2011). |
| 22. Definition of the ecosystem value proposition (COHEN-ROSENTHAL, 2003; CÔTÉ; COHEN-ROSENTHAL, 1998; KAPLAN; NORTON, 2000; 2005; 2008; PORTER; KRAMER, 2006; 2011). |
| 23. Definition of financial symbioses: *(a) The creation of synergy through effective management of internal capital and labour markets* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 24. Definition of financial symbioses: *(b) The integration of a diverse set of businesses around a single brand, promoting common values or themes* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 25. Definition of stakeholder symbioses: *(c) The creation of value through cross-selling a broad range of products and services from several business organizations* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 26. Definition of stakeholder symbioses: *(d) The creation of a consistent buying experience, conforming to corporate standards at multiple outlets* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 27. Definition of process symbioses: *(e) The creation of economies of scale by sharing the systems, facilities, and personnel in critical support processes* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 28. Definition of process symbioses: *(f) The creation of value by integrating contiguous processes in the industry value chain* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 29. Definition of knowledge symbioses: *(g) Share competency in the development of human, information, and organizational capital* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 30. Definition of the human capital capabilities required (KAPLAN; NORTON, 2000; 2005; 2008). |
| 31. Definition of the technology enablers of the strategy (KAPLAN; NORTON, 2000; 2005; 2008). |
| 32. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(a) creating learning and growth through human capital, informational technology capital and organizational capital* (KAPLAN; NORTON, 2000; 2005; 2008). |

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| 33. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(b)integrating practices, activities in the value chain performed in ways that reinforce improvements in the social dimensions of context* (KAPLAN; NORTON, 2000; 2005; 2008). |
| 34. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(c)creating a social dimension to the value proposition that attends customers, civil society and natural ecosystem* (KAPLAN; NORTON, 2000; 2005; 2008). |
| **III. Alignment management** |
| 35. Formal communication process of industrial ecosystem strategy to managers of organizations that operates within the industrial ecosystem (KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 36. Support organizations that operate within the industrial ecosystem to translate the industrial ecosystem strategy into industrial symbiosis strategy (KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| **IV. Industrial symbiosis management** |
| 37. Development of industrial symbiosis strategy: *analyses of industrial ecosystem's strategic objectives, measures, targets, initiatives, budget and accountability* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 38. Planning of financial symbioses: *(a)The creation of synergy through effective management of internal capital and labour markets* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 39. Planning of financial symbioses: *(b) The integration of a diverse set of businesses around a single brand, promoting common values or themes* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 40. Planning of stakeholder symbioses: *(c) The creation of value through cross-selling a broad range of products and services from several business organizations* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 41. Planning of stakeholder symbioses: *(d) The creation of a consistent buying experience, conforming to corporate standards at multiple outlets* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 42. Planning of process symbioses: *(e) The creation of economies of scale by sharing the systems, facilities, and personnel in critical support processes* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 43. Planning of process symbioses: *(f) The creation of value by integrating contiguous processes in the industry value chain* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 44. Planning of knowledge symbioses: *(g) Share competency in the development of human, information, and organizational capital* (CHERTOW, 2000; 2007; KAPLAN; NORTON, 2006; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 45. Definition of the human capital capabilities required (KAPLAN; NORTON, 2000; 2005; 2008). |
| 46. Definition of the technology enablers of the strategy (KAPLAN; NORTON, 2000; 2005; 2008). |
| 47. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(a) financial symbioses* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 48. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(b)stakeholder symbioses* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 49. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(c)process symbioses* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 50. Developing strategic objectives, measures, targets, initiatives, and budget that guide action, resource allocation and accountability structure for *(d)knowledge symbioses* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |

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|---|
| 51. Alignment of employees with industrial symbiosis strategy through communication and incentives (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 52. Planning operations of industrial symbiosis: *(a) Improvement of key processes for financial symbiosis* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 53. Planning operations of industrial symbiosis: *(b) Improvement of key processes for stakeholder symbiosis* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 54. Planning operations of industrial symbiosis: *(c) Improvement of key processes for process symbiosis* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 55. Planning operations of industrial symbiosis: *(d) Improvement of key processes for knowledge symbiosis* (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 56. Monitoring of execution of industrial symbiosis (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| 57. Adaptation of industrial symbiosis strategy opportunely (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| **V. Accountability management** |
| 58. Monitor and learn about problems, barriers, and challenges through metrics (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |
| **VI. System adaptation management** |
| 59. Use of internal operational data and new external environmental and competitive data to test and adapt the industrial ecosystem strategy, launching another loop around the integrated strategy planning and operational execution system (KAPLAN; NORTON, 2000; 2005; 2006; 2008; KAPLAN; NORTON; RUGELSJOEN, 2010). |

Source: Adapted by the author.

### *2.2.2 Selecting case*

Over the course of this research step, the main issue faced by the researcher was where to sample or go for gathering data for the further development of 59 a priori constructs. To identify, develop, and relate these emergent concepts, the researcher used “theoretical sampling,” which is the process of selecting cases based on theoretical rather than statistical criteria (EISENHARDT, 1989; STRAUSS; CORBIN, 2008). Cases are chosen in this manner to fill theoretical categories and provide guiding principles (EISENHARDT, 1989; Strauss; Corbin, 2008). They may be selected randomly, but Eisenhardt (1989) argues random selection is neither necessary nor even preferable, as it could lead the researcher down unproductive paths and change the research focus. To avoid this issue, Eisenhardt (1989) recommends selecting cases that are defined as extreme situations and polar types, and where the process of interest is clearly visible.

Therefore, the researcher had to work carefully with theoretical sampling rather than let it happen randomly. To choose a case that was likely to advance 59 a-priori constructs, the researcher selected one industrial ecosystem fostered by, but not belonging to, Natura Cosméticos S.A., a cosmetic firm that figured as number two on the 2012 Global 100 List[18]. This decision relied on three factors. Firstly, the industrial ecosystem selected is a polar type in an extreme situation. It includes a biodiversity-based production system in the Amazon Rainforest of Brazil's northern region[19]. Second, it unequivocally demonstrates the process of interest of this current research, which is eco-industrial development by means of imitation of the organizational properties of a type III ecosystem using a top-down approach, i.e., under a single, central authority. At last, this particular case introduces the "Model of Business Engagement" conceived by Natura (2011), which is a set of guiding principles for management processes towards sustainability that may comprise a fundamental management approach to other industrial ecosystems.

In the midst of theoretical sampling, the researcher identified the action process of interest for this study in a film[20] on the industrial ecosystem supported by Natura in Benevides, Pará. Moreover, several sources indicated the presence of the management of eco-industrial development. According to the administration's report to investors, Natura's goal is to "consistently contribute to the transition of society towards sustainable development by building a business model that integrates economic growth with social and environmental objectives" (NATURA, 2011). Through theoretical comparison (STRAUSS; CORBIN, 2008), this purpose is consistent with Cohen-Rosenthal's (2003) and Côté and Cohen-Rosenthal's (1998) ideas of eco-industrial development.

As disclosed in the same document, the achievement of that objective is contingent on investments in "conscientious and genuinely interested leaders in environmental issues and economic and social development; innovative strategies and initiatives; and robust processes that enable performance monitoring" (NATURA, 2011). This clause pertains to Aggregator 2, which discusses the management of an industrial ecosystem to attain a high level of eco-industrial development.

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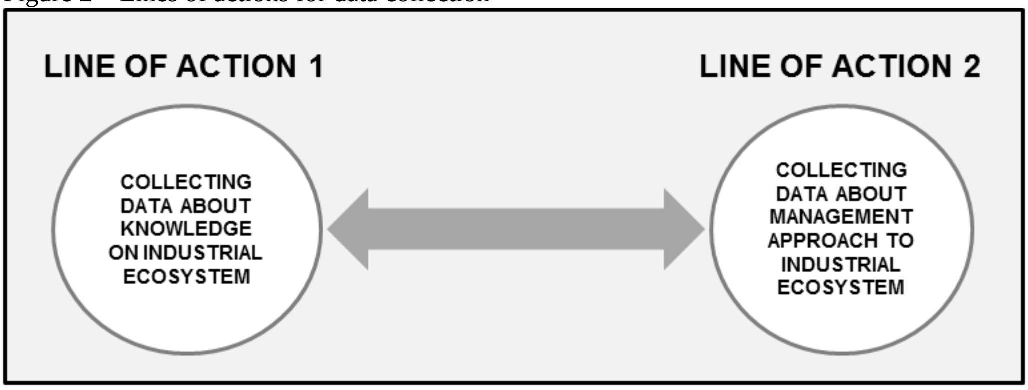
[18] The Benevides Industrial Ecosystem was proposed by Professor Raymond P. Côté, a former consultant for Natura in eco-industrial development. The BIU general manager authorized the field research after receiving the data collection letter (APPENDIX A).
[19] More specifically, it is in the city of Benevides, in the state of Pará, in the Amazon Rainforest, in the North Region of Brazil.
[20] The film was offered by Professor Raymond P. Côté, co-supervisor of this thesis.

### 2.2.3 *Crafting instruments and protocols*

Eisenhardt (1989) and Strauss and Corbin (2008) advise creating an initial list of interview questions and areas for observation using concepts derived from literature, experience, or previous field research. Following that, the researcher applied the a priori framework derived from the literature presented in Table 2 as a starting point to craft research instruments and to begin data collection. Even though the development of this framework did not rely on actual data, the researcher applied it in the field, but it was regarded as provisional and its components were discarded as real data started to appear. Due to the difference in properties and dimensions among constructs belonging to the a priori framework, as a consequence of the previous specification of constructs illustrated in Figure 1, the researcher has defined two distinct lines of action for data collection. As Figure 2 shows, the first one is focused on the knowledge of the industrial ecosystem, and the second is more related to the management approach to eco-industrial development. However, they are complementary to each other.

Figure 2 – Lines of actions for data collection




Source: Adapted by the author.

After selecting the local, the informants, the timing, the types of data to be collected, and taking into account the further data analysis stages, the researcher developed a data-gathering scheme based on these two lines of action that are complementary and simultaneous. Through a methodological triangulation, the researcher defined for each line of action its own epistemological approach, research approach, data collection methods, research sources, categories, subcategories, and outcomes. The summary of this data-gathering scheme can be found in Table 3, which clarifies the relationship between the data-gathering stages, techniques, and end results.

As indicated in Table 3, the goal of Line of Action 1 was to provide data for “why questions” regarding the management of eco-industrial development. To this end, the researcher developed a list of topics for interview questions, observation, and document gathering (detailed in Appendix B) in order to collect data about the beliefs concerning the industrial ecosystem and its subsequent effects. The data collected about both of these themes relates primarily to the category “description of an industrial ecosystem” and its subcategories. Throughout this data-gathering stage, the researcher obtained information on the characteristics of an industrial ecosystem, observing the existence of functions and mechanisms that mimicked those found in a natural ecosystem of type III. Most importantly, the analyst searched for information on the goal of an industrial ecosystem and its benefits to society and the environment.

Table 3 – Data-gathering framework

| **LINE OF ACTION 1** | | **LINE OF ACTION 2** | |
|---|---|---|---|
| Data gathering on knowledge on industrial ecosystem | | Data gathering on management approach to IE | |
| **EPISTEMOLOGICAL APPROACH** | | **EPISTEMOLOGICAL APPROACH** | |
| Double hermeneutic | | Double hermeneutic | |
| **RESEARCH APPROACH** | | **RESEARCH APPROACH** | |
| Qualitative | | Qualitative | |
| **1ST DATA COLLECTION** | | **1STDATA COLLECTION** | |
| Semi-structured interview<br>Document gathering<br>Non-participant observation | | Semi-structured interview<br>Document gathering<br>Non-participant observation | |
| **INFORMANTS** | | **INFORMANTS** | |
| 10 managers from the chosen industrial ecosystem | | 10 managers from the chosen industrial ecosystem | |
| **CATEGORY[21]** | **SUBCATEGORY** | **CATEGORY** | **SUBCATEGORY** |
| I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. | II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. |
| | | III. Alignment management | 35, 36. |
| | | IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. |
| | | V. Accountability management | 58 |
| | | VI. System adaptation management | 59 |
| **OUTCOMES** | | **OUTCOMES** | |
| Transcripts from interviews with 10 managers<br>Documents on attributes of industrial ecosystem<br>Observation notes | | Transcripts from interviews with 10 managers<br>Documents on management approach<br>Observation notes | |
| **2ND DATA COLLECTION** | | **2ND DATA COLLECTION** | |
| Literature research | | Literature research | |
| **SOURCES** | | **SOURCES** | |
| Academic papers on eco-industrial development and industrial symbiosis published between 2007 and 2012 | | Academic papers on eco-industrial development and industrial symbiosis published between 2007 and 2012 | |

[21]All categories and subcategories in Table 3 correspond to the a priori constructs from Table 2.

| CATEGORY[10] | SUBCATEGORY[11] | CATEGORY[12] | SUBCATEGORY[13] |
|---|---|---|---|
| I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. | II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. |
| | | III. Alignment management | 35, 36. |
| | | IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. |
| | | V. Accountability management | 58 |
| | | VI. System adaptation management | 59 |
| **OUTCOMES** | Evidential data similar to emerging categories and subcategories | **OUTCOMES** | Evidential data similar to emerging categories and subcategories |

Source: Adapted by the author.

Table 3 also depicts the second line of action, which aimed to provide specific data for answering “how questions” about the management of eco-industrial development. To this end, the researcher developed a list of topics for interview questions, observation, and document gathering (detailed in Appendix B) for collecting data about knowledge on the action of managing toward eco-industrial development. The data gathered about this theme relates directly to five categories: “industrial ecosystem strategy,” “alignment management,” “industrial symbiosis management,” “accountability management,” “system adaptation management,” and their subcategories. During this phase of data collection, the researcher discovered a series of actions that progress toward eco-industrial development over time and space.

For the first cycle of data collection, the researcher conducted ten semi-structured interviews[22] for both lines of action based on a script presented in Appendix B. Unstructured interviews utilized merely the general guidelines suggested by Strauss and Corbin (2008) to introduce topics from the script, such as “tell me what you think about...”, “what happens when...”, and “what is your experience with...” These types of questions permit respondents to freely express their priorities (STRAUSS; CORBIN, 2008). Then, the respondents’ answers were compared, and the concepts that emerged served as the foundation for the collection of additional data.

In view of the managers’ limited knowledge on social action, the researcher employed document gathering[23] in accordance with the script shown in Appendix B. This procedure included the verification of evidentiary documents related to the concepts that emerged

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[22] The researcher conducted ten semi-structured interviews between November 28 and December 2, 2011.
[23] Data gathering was carried out concurrently with interviews.

during interviews. This checking process was carried out by the researcher during the length of his stay at Natura's plant. Based on the same epistemological principle exposed above, a non-participant observation was held following the same script found in Appendix B. All data obtained through the first cycle of data gathering was applied to the processes of within-case analysis and hypothesis shaping, detailed respectively in subsections 2.2.5 and 2.2.6.

The second cycle of data collection for both lines of action involved using Nvivo for literature review, as suggested by Di Gregorio (2000). The scope of the data collection included scholarly articles on eco-industrial development and industrial symbiosis published between 2007 and 2012. This procedure aimed to collect evidence-based data from the literature corresponding to the categories and subcategories of the emerging theoretical framework. According to Strauss and Corbin (2008), empirical data from related literature enhances the definition and generalization of constructs and raises their theoretical level. All of the data gathered in the second cycle of data collection was used in the comparison analysis with similar literature, which is described in section 2.2.7.

### *2.2.4 Entering the field*

The first cycle of data gathering for both lines of action was carried out by the researcher through ten semi-structured interviews based on a script presented in Appendix B. The interviews lasted approximately one hour each, and the answers were recorded with the permission of the interviewees. After that, the researcher typed up all of the answers that had been recorded so that the analysis could be done.

As an exploratory research project on the management approach to eco-industrial development, the objective of the field research was to keep the data collection process open to all possibilities. On the first day, sampling was open to all people and places in the industrial ecosystem analyzed in order to ensure greater opportunities for discovery. The choice of people to talk to or places to observe was made by BIU general manager, who gave a list of names, places, and times, as well as the resources needed to conduct the procedure.

At first, the researcher had limited knowledge of the industrial ecosystem studied, so it was difficult for him to decide where to go to search for data about the a priori constructs. Therefore, the researcher was open to all possibilities during interviews, observations, and readings. The tactic was to take full advantage of every opportunity that emerged, exploring each source as much as possible. To ensure openness, the researcher did not structure the data gathering very closely in terms of timing or types of people or places.

Open sampling required the researcher to feel comfortable while waiting for something to happen or for someone to say something interesting. The ability to conduct interviews evolved over time, beginning with the third. The first interview was very awkward, whereas the last one became much richer in data. The researcher tried hard not to put informants on the defensive by unconsciously signaling to them to respond or act in expected ways. He attempted to maintain a balance between "systematic data collection" based on a list of questions and areas for observation, which allows the development of categories, and "flexibility," which allows facts, events, and interviews to float freely.

Due to the short time available, specifically one week, data collection was not immediately followed by analysis. In view of this, the researcher focused on collecting data before analyzing what was in his hands. Consequently, the researcher did not have the opportunity to sample based on emerging concepts. On the other hand, during interviews, document gathering, and observations, due to increased sensitivity, the researcher could recognize the emerging concepts that seemed readily noticeable. When something significant emerged, the researcher asked for additional explanations. In terms of procedure, the researcher acted very systematically, going from one person to another or from one place to another based on a list provided by Natura's senior manager and sampling based on convenience.

### *2.2.5 Analyzing within-case data*

Data analysis is at the heart of developing theory from case studies (EISENHARDT, 1989). It is a systematic search for meaning that entails synthesis, evaluation, interpretation, categorization, hypothesizing, comparison, and pattern finding (HATCH, 2002). Following recommendations by Leech and Onwuegbuzie (2007; 2008; 2011) for increasing the rigor and trustworthiness of qualitative data findings, the researcher utilized a triangulation of data analysis, which is detailed in the analytical scheme shown in Table 4. To fully comprehend the phenomenon of eco-industrial development management, multiple data analysis techniques were employed.

Table 4 – The analytical scheme for developing the theoretical framework

| **STEP 1** | **STEP 2** |
|---|---|
| Within-case analysis | Coding to gather evidence of an action process |
| **EPISTEMOLOGICAL APPROACH** | **EPISTEMOLOGICAL APPROACH** |
| Double hermeneutic | Double hermeneutic |
| **DATA ANALYSIS TECHNIQUES** | **DATA ANALYSIS TECHNIQUES** |
| Constant comparison analysis based on deductive coding (open and axial) | Constant comparison analysis based on deductive coding (open, axial, and selective) |

| SOURCES | | SOURCES | |
|---|---|---|---|
| Material from the first cycles of data collection | | Material from within-case analysis | |
| REFERENCE POINTS | | REFERENCE POINTS | |
| CATEGORY[24] | SUBCATEGORY | CATEGORY | SUBCATEGORY |
| I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. | I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. |
| II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. | II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. |
| III. Alignment management | 35, 36. | III. Alignment management | 35, 36. |
| IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. | IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. |
| V. Accountability management | 58 | V. Accountability management | 58 |
| VI. System adaptation management | 59 | VI. System adaptation management | 59 |
| OUTCOMES | | OUTCOMES | |
| Chapter 03 | | Chapter 04 & Chapter 05 | |
| STEP3 | | STEP4 | |
| Literature review | | Theoretical framework validation by comparison with literature | |
| EPISTEMOLOGICAL APPROACH | | EPISTEMOLOGICAL APPROACH | |
| Double hermeneutic | | Double hermeneutic | |
| DATA ANALYSIS TECHNIQUES | | DATA ANALYSIS TECHNIQUES | |
| Constant comparison analysis based on deductive coding (open and axial) | | Text search, word frequency, group queries by NVivo 10 to find items associated with others items | |
| SOURCES | | SOURCES | |
| Material from the second cycles of data collection | | Material from coding for finding process and literature review | |
| REFERENCE POINTS | | REFERENCE POINTS | |
| CATEGORY | SUBCATEGORY | CATEGORY | SUBCATEGORY |
| I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. | I. Description of industrial ecosystem | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. |
| II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. | II. Industrial ecosystem strategy | 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34. |
| III. Alignment management | 35, 36. | III. Alignment management | 35, 36. |
| IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. | IV. Industrial symbiosis management | 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57. |
| V. Accountability management | 58 | V. Accountability management | 58 |
| VI. System adaptation management | 59 | VI. System adaptation management | 59 |
| OUTCOMES | | OUTCOMES | |
| Chapter 04 & Chapter 05 | | Chapter 04 & Chapter 05 | |

Source: Adapted by the author.

[24] All categories and subcategories in Table 04 correspond to the categories and subcategories from Table 03.

A within-case analysis was the first step in the analytical phase. The choice of within-case analysis was driven by the overwhelming volume of data generated as a result of the open-ended interview questions. Eisenhardt (1989) states that within-case analysis can help researchers become intimately familiar with each case as a stand-alone entity. This method enables pattern recognition before researchers hypothesize. It often produces a detailed case study write-up, which is a pure description essential to the generation of insight. However, no standard format for such an analysis exists (EISENHARDT, 1989). For carrying out the within-case analysis, the researcher applyed "constant comparison analysis,"[25] the most commonly used procedure of analysis for qualitative data created by Glaser and Strauss (1967). The goal of constant comparison analysis is to develop a theory or set of themes (constructs) (LEECH; ONWUEGBUZIE, 2007; 2008; 2011; STRAUSS; CORBIN, 2008).

Over the course of within-case analysis, the researcher was simply interested in pattern finding, utilizing the entire dataset generated in the first cycles of data collection to identify underlying themes (constructs) presented in the data. For strictly creating a set of themes, "constant comparison analysis" was undertaken "deductively," as suggested by Eisenhardt (1989) and Strauss and Corbin (2008). Thus, all categories and subcategories identified in the a priori specification of constructs presented in Table 2 were searched for in the raw data. Firstly, the researcher employed "open coding." In doing so, he split his data into separate parts and gave each one a "code," which is a rough construct. Then, the researcher applied "axial coding" to arrange his codes and underlying data based on their correlations with a priori constructs listed in Table 4. Following axial coding, the researcher was equipped with a list of categories and subcategories supported by a simplified set of supplementary codes. At the end, the categories and subcategories and their corresponding references (sentences) helped to produce the detailed case study write-up about the industrial ecosystem fostered by Natura discussed in Chapter 3.

### *2.2.6 Shaping hypotheses*

As specified in Table 4, the second step of the analytical phase entailed coding to find an action process and its sub-processes. The researcher focused on "process coding" because recognizing the management process for eco-industrial development through analysis

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[25] Glaser and Strauss (1967) came up with a method called "constant comparative analysis" that is used to build theories. In this method, raw data excerpts are put into "constructs" based on their characteristics, and then those "constructs" are put in a logical order to form a new theory.

was an important part of the entire elaboration of the proposed theoretical framework. The aim of the second data analysis stage was to write abstractly about the management process for EID: (i) specifically naming it, (ii) conceptually developing it, and (iii) systematically connecting it within a theoretical framework with other concepts. This data analysis procedure employed the same techniques of constant comparison analysis suggested by Glaser and Strauss (1967). However, instead of searching for properties, the researcher observed purposeful action[26] and noticed motion, sequence, and change. In particular, the researcher wanted to know how the management of EID changes when the situation or context changes.

For recognizing the process of managing EID in Step 2, constant comparison analysis was undertaken "deductively," as recommended by Eisenhardt (1989) and Strauss and Corbin (2008). Thus, all a priori categories and their subcategories[27] exhibited in Table 4 were searched for within the data produced by the within-case analysis. The overall procedure of coding to gather evidence of the management process of EID and its sub-processes involved the following data analysis techniques, according to Eisenhardt (1989) and Strauss and Corbin (2008): (i) open coding; (ii) axial coding; and (iii) selective coding[28]. The goal of the first two procedures was to name the sub-processes of MEID and the activities that supported them. The third step was to put them all together in a theoretical framework in a way that made sense.

### *2.2.7 Enfolding literature*

The resulting theoretical framework produced by Step 2 of the analytical phase was validated through comparison with the literature (see Steps 3 and 4 in Table 4). It is an important aspect of developing theory from a case study, according to Eisenhardt (1989). After isolating codes and establishing connections between them, the researcher asked the resulting nodes what the following literature had in common with the emerging theoretical framework and why:

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[26] As discussed in Section 2.1, the actions of individuals make up an action process that may be strategic, taken in response to problematic situations, or may be routine, performed almost without thinking (STRAUSS; CORBIN, 2008). Still, in accordance with Strauss and Corbin (2008), the action process can generally be divided into sub-processes, which are typically individual tactics, strategies, and ordinary actions that make up the ultimate act. In the context of the current research, this epistemological approach by Strauss and Corbin (2008) is translated as follows: the actions of managing the industrial ecosystem in time and space make up the management process for eco-industrial development, which can usually be divided into sub-processes (strategies, tactics, and routine).

[27] In coding to gather evidence of a process, an a priori category and its subcategories refer respectively to the sub-process and its supporting activities. A series of sub-processes and their supporting activities make up the ultimate process. In the context of the current research, the a priori category and its subcategories refer to a subprocess of the management approach for EID and its supporting activities. A series of sub-processes for managing EID and their supporting activities make up the ultimate process, treated here as the management process for EID.

[28] The details on the application of open coding, axial coding, and selective coding are found in Chapter 4.

Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010)[29]. These authors describe the management processes adopted by the world-renowned initiatives of eco-industrial development.

Due to the fact that the primary data in this study are based on a single case, the analytical procedure of comparing them to the literature was extremely important. As recommended by Eisenhardt (1989), the researcher linked, by means of open coding and axial coding, the emergent categories and subcategories to existing literature in order to strengthen the internal validity, generalizability, and theoretical level of the proposed theoretical framework. To establish connections between emerging constructs and the previously mentioned journal articles, he utilized Di Gregorio's (2000) NVivo literature review methodology. As shown in Table 4, the goal of Steps 3 and 4 of the data analysis was to collect evidence-based data from the literature that was similar to the categories and subcategories (constructs) shown in the emerging theoretical framework created in Step 2.

The comparison with the literature was done by looking for specific words, phrases, or ideas in the scientific articles and coding them at the emerging categories and subcategories developed in Step 2. To do so, the researcher selected key words, phrases, or concepts from the emerging theoretical framework first and then ran text search queries and word frequency queries in NVivo 10. Thereafter, he coded the scientific articles and brought the references (sentences) together in a single node, which is the reference to a specific category or subcategory (a construct) in the proposed framework. Further, the researcher labeled each new node with a descriptive title similar to the name of the category or subcategory it refers to. After all journal articles were coded, the nodes were grouped by similarity, and categories and subcategories were validated and documented based on each grouping. At the end, the nodes and their corresponding references (sentences) from literature helped to generate the ultimate theoretical framework for the management of an industrial ecosystem, as detailed in Chapter 5.

[29] These journal articles were identified in the second cycle of data gathering (TABLE 3). The scope of the data collection included scholarly articles on eco-industrial development and industrial symbiosis published between 2007 and 2012.

## 3 THE CASE STUDY: BENEVIDES INDUSTRIAL ECOSYSTEM

This chapter presents a detailed case study report on the Benevides Industrial Ecosystem (BIE) fostered by Natura Cosméticos S.A., a cosmetic company whose products are derived from biodiversity. The Benevides Industrial Ecosystem has special characteristics due to its location near suppliers of natural essences in the geo-economic region of the Amazon[30], in the northern region of Brazil.

The complete description of BIE is elaborated as a result of Line of Action 01, as described in Chapter 2. It aims to provide specific responses to "why questions" regarding the management of eco-industrial development. To that matter, it brings information that describes the managers' beliefs concerning the industrial ecosystem and its subsequent effects. These two themes are primarily associated with the category "Description of the industrial ecosystem" and its subcategories, which are summarized in Table 5.

Table 5 – The theme node "description of industrial ecosystem" and its subcategories

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| Description of industrial ecosystem | 14 | 627 | 02/07/2012 11:20 AM | LQ |
| 1. Inspiring strategy for industrial ecosystem develo | 4 | 17 | 02/07/2012 11:21 AM | LQ |
| 10. Industrial ecosystem goal | 3 | 14 | 02/07/2012 11:34 AM | LQ |
| 11. Outcome of the conservation of ecosystem servi | 2 | 2 | 02/07/2012 11:38 AM | LQ |
| 12. Reason for investing in human well-being and p | 3 | 15 | 02/07/2012 11:35 AM | LQ |
| 13. Outcome of the destruction of ecosystem servic | 1 | 1 | 02/07/2012 11:39 AM | LQ |
| 14. Mechanisms for cluster development | 7 | 57 | 02/07/2012 11:40 AM | LQ |
| 15. Indirect mechanisms | 8 | 56 | 02/07/2012 11:40 AM | LQ |
| 16. Direct mechanisms | 9 | 54 | 02/07/2012 11:41 AM | LQ |
| 17. Property of industrial ecosystem | 12 | 124 | 02/07/2012 11:42 AM | LQ |
| i. Shareholder Value | 4 | 19 | 05/07/2012 9:51 AM | LQ |
| 18. The office of eco-relationships management | 9 | 128 | 02/07/2012 11:42 AM | LQ |
| 2. Theoretical background for industrial ecosystem | 9 | 40 | 02/07/2012 11:23 AM | LQ |
| 3. Primary components | 5 | 25 | 02/07/2012 11:24 AM | LQ |
| 4. Primary components' functions | 4 | 23 | 02/07/2012 11:26 AM | LQ |
| 5. Secondary components | 1 | 1 | 02/07/2012 11:28 AM | LQ |
| 6. Secondary components' functions | 2 | 4 | 02/07/2012 11:29 AM | LQ |
| 7. Industrial ecosystem development | 11 | 30 | 02/07/2012 11:30 AM | LQ |
| 8. Assessment of industrial ecosystem development | 2 | 2 | 02/07/2012 11:33 AM | LQ |
| 9. Operation of homeostasis in an industrial ecosyst | 8 | 34 | 02/07/2012 11:34 AM | LQ |

Source: Adapted by the author from NVivo 10.

[30] The geo-economic region of the Amazon encompasses all northern states of Brazil (except the extreme south of Tocantins), virtually the entirety of Mato Grosso, and western of Maranhão, an area of approximately 5.1 million square kilometers (approximately 60 percent of the country's territory) distributed across nine states, and is the least populous geo-economic region.

Multiple data collection techniques were used to create a description of BIE, including semi-structured interviews with managers from Natura and other BIE companies, document gathering, including texts, videos, and images, and non-participant observation. Table 6 lists all internal source materials produced during this data collection. They have been coded under the category "description of industrial ecosystems" and its subcategories. Table 6 displays the name of the internal sources that were coded in this category, the number of references that were coded, and the percentage of the coding coverage in the sources.

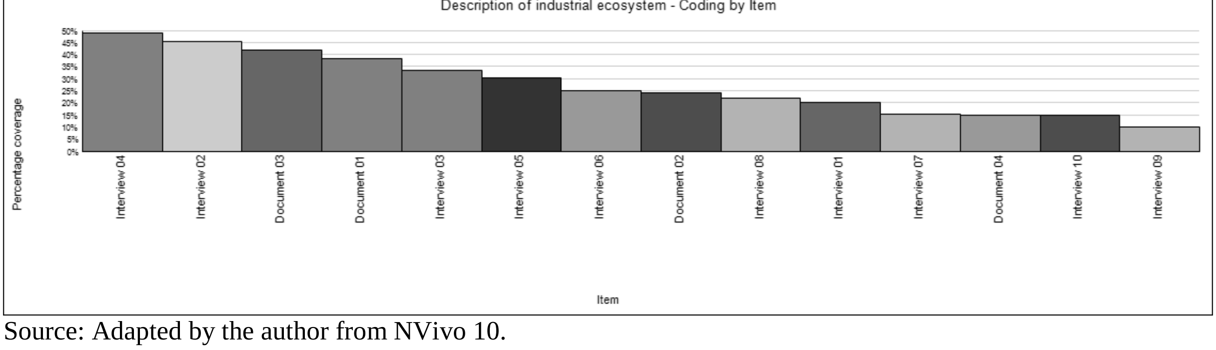
Table 6 – The internal source materials coded at "description of industrial ecosystem"

| Name | In Folder | References | Coverage |
|---|---|---|---|
| Document 01 | Internals\\Documents | 51 | 38.39% |
| Document 02 | Internals\\Documents | 19 | 24.53% |
| Document 03 | Internals\\Documents | 30 | 42.20% |
| Document 04 | Internals\\Documents | 12 | 14.95% |
| Interview 01 | Internals\\Interviews | 39 | 20.36% |
| Interview 02 | Internals\\Interviews | 127 | 45.66% |
| Interview 03 | Internals\\Interviews | 60 | 33.78% |
| Interview 04 | Internals\\Interviews | 110 | 48.91% |
| Interview 05 | Internals\\Interviews | 29 | 30.39% |
| Interview 06 | Internals\\Interviews | 55 | 25.07% |
| Interview 07 | Internals\\Interviews | 21 | 15.59% |
| Interview 08 | Internals\\Interviews | 48 | 21.97% |
| Interview 09 | Internals\\Interviews | 16 | 10.25% |
| Interview 10 | Internals\\Interviews | 10 | 14.85% |

Source: Adapted by the author from NVivo 10.

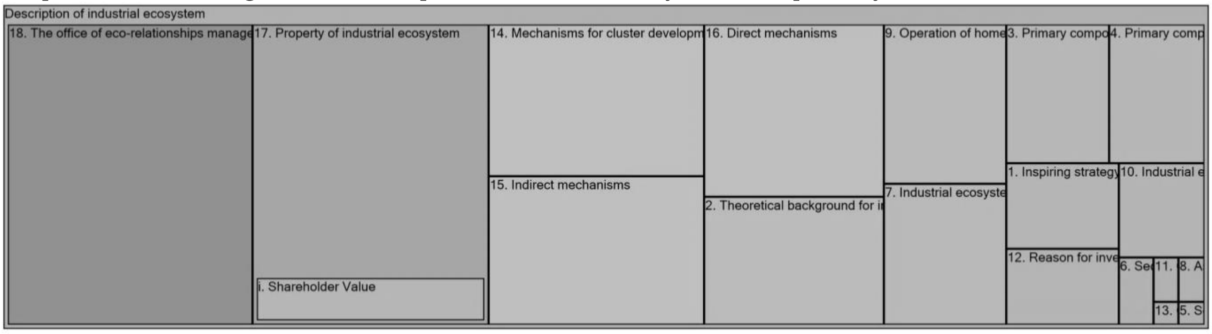
The percentage of each source coded in the category "description of the industrial ecosystem" is depicted in Graph 1. In order to display the most frequently discussed topics by interviewees regarding the category "description of the industrial ecosystem," Graph 2 exhibits, on the next page, a tree map with the subcategories compared by the number of coded references.

Graph 1 – The percentage of each internal source coded at "description of industrial ecosystem"




Source: Adapted by the author from NVivo 10.

Graph 2 – The subcategories of “description of industrial ecosystem” compared by number of coded references




Source: Adapted by the author from NVivo 10.

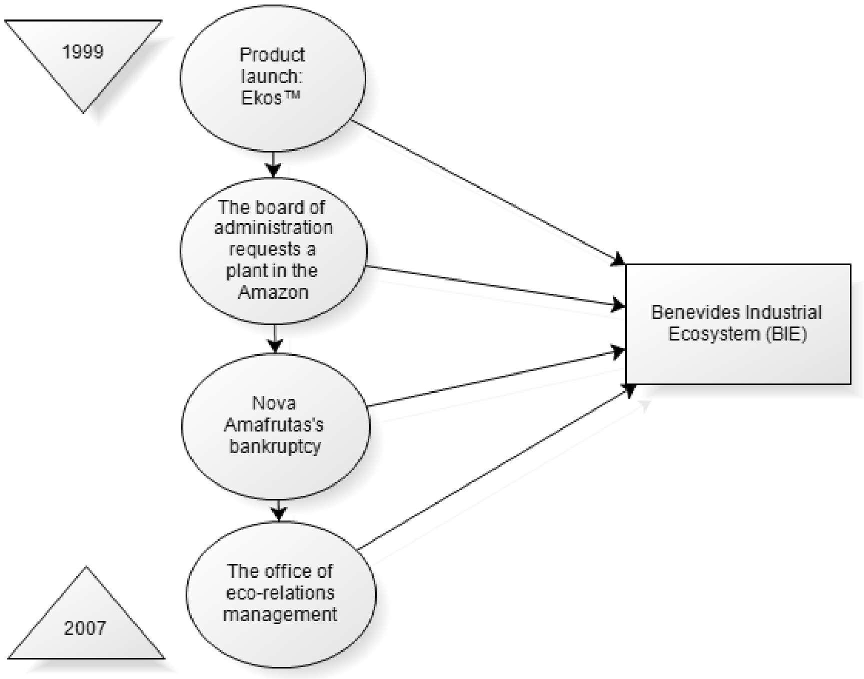
The description of BIE is outlined in this chapter, not necessarily in accordance with Table 5. Initially, sections 3.1, 3.2, and 3.3 discuss the key factors that triggered the eco-industrial development in Benevides. The following sections detail the features of the Benevides Industrial Ecosystem. They highlight the action of managing eco-industrial development, which has fostered a social system with functions and mechanisms that mimic those found in a natural ecosystem of type III. Most importantly, it explains the goal of BIE and its benefits to society and the environment in the Amazon geoeconomic region.

### 3.1 The origin of Benevides Industrial Ecosystem

The Benevides Industrial Ecosystem is an economic system created by the decisions, actions, and attitudes of Natura’s business managers between 1999 and 2007. For the purposes of this study, their specific actions are referred to as “management of eco-industrial development.” Their actions under MEID were strategic and were taken in response to the challenging situations Natura faced during those years. Graph 3 demonstrates four key factors arranged in sequential order and makes it possible to comprehend why Natura business managers decided to develop an industrial ecosystem in Benevides, Pará. Moreover, their actions under MEID consistently show how a company, as a group of individuals, aligned its actions with an emerging social structure[31] in order to sustain its financial growth.

[31] By “emerging social structure,” I mean the set of values, rules, and social institutions for addressing environmental issues resulting from the environmental movement carried out in the last quarter of the twentieth century.

Graph 3 – The key factors for the eco-industrial development in Benevides




Source: Adapted by the author from NVivo 10.

The first condition for the formation of the Benevides Industrial Ecosystem was met in 1999, when Natura began using essences derived from Amazon forest plants in the research and development (R&D) of its Natura Ekos cosmetics line[32]. In order to obtain the plants necessary for manufacturing Natura Ekos products, the managers had to establish a new supply chain model based on relationships with cooperatives owned and operated by groups of farm workers. Through this supply chain, Natura started to acquire fourteen Brazilian biodiversity products from family farming cooperatives in 23 rural communities distributed across all biomes of Brazil[33], employing a total of 2,731 farm worker families[34]. Figure 3 demonstrates that the state of Pará, which is located in the geo-economic region of the Amazon, has the greatest number of rural communities that provide biodiversity products to Natura.

[32] To minimize environmental impact, Natura Ekos products are developed using green technologies. They have formulas based on essences from Brazilian plants. Its manufacturing process prioritizes the use of raw materials from renewable sources and plants with certifications of origin, either organic farming or sustainable forest management. Natura Ekos also uses recyclable packaging made of recycled materials (NATURA, 2012d).
[33] The biomes are Atlantic Forest, Southern Fields, Scrubland, and Amazon Forest.
[34] According to Natura (2012d), the data was updated in December 2011.

Figure 3 – The localization of the family farming cooperatives


Source: Adapted by the author from Natura Ekos's website.

A second factor contributed to the emergence of BIE in 2003. A key member of the board of administration requested at that time that the manufacturing team develop an operational model based on industrial ecology principles. The objective was to leverage access to Brazilian biodiversity products in the GRA, given that a significant number of rural communities in this region harvest forest products. This business strategy aimed to ensure a steady supply of biodiversity products, a crucial success factor for the continued market presence of Natura Ekos. In order to implement the industrial ecology principles in the GRA, initiatives have been designed to generate significant socioeconomic and environmental benefits in one of Brazil's most prominent regions. According to the board of administration, these initiatives should:

a) generate income for families involved in the harvesting of biodiversity products, making the participation in Natura's supply chain appealing;
b) value all biodiversity products in monetary terms to prevent both monoculture and irregular deforestation;
c) apply the concepts of industrial ecology, such as the use of by-products in manufacturing, to reduce the impacts of Natura's operations in the GRA.

Shortly after the request from the board of administration, the manufacturing operations managers formed a partnership with Nova Amafrutas, a family farming cooperative specializing in the harvesting of passion fruit and acerola and the production of frozen pulp made from these fruits. This partnership aimed to increase the value of these fruits in order to: (i) improve the living conditions of 2,500 farm worker families affiliated with Nova Amafrutas; (ii) establish a reliable supply chain; and (iii) obtain raw materials. In the agreement, Natura should expand the demand for farm workers' products by constructing a passion fruit oil extraction facility. Nova Amafrutas, on the other hand, should profitably manage this facility under a free-lease agreement and supply passion fruit oil to Natura's Cajamar Industrial Unit in São Paulo on a regular basis. The construction of the passion fruit oil extraction facility began at the end of 2004 in Benevides, in the Brazilian state of Pará.

Since the beginning of their partnership with Nova Amafrutas, Natura's managers have intended to integrate the extraction of passion fruit oil in Benevides into an industrial symbiosis. The passion fruit oil extraction facility was therefore designed to utilize byproducts from the production of frozen passion fruit pulp by Nova Amafrutas. As a result, Nova Amafrutas and the passion fruit oil extraction facility were physically connected by tracks that transport passion fruit seeds (by-products) for processing into passion fruit oil. It would be used in the production of cosmetics by the Cajamar Industrial Unit of Natura.

However, due to political and administrative issues, Nova Amafrutas declared bankruptcy in 2006[35]. Consequently, Natura was compelled to assume the responsibilities of the passion fruit oil extraction facility to maintain the supply chain. At that time, in order to establish an eco-friendly brand identity, all Natura bath soap lines were formulated with vegetable fats and oils. As a result, it was critical to obtain vegetable fats and oils in order to green its products. Natura would not have eco-products and would have lost all investments in innovation if it had not taken responsibility for fruit oil extraction in Benevides. The solution created by Natura was to send a management team to Benevides to maintain the oil extraction facility and operationalize the already-established concept of industrial symbiosis.

In 2007, under the direction of Natura, the former fruit oil extraction facility was transformed into the Benevides Industrial Unit (BIU), which was intended to be a sustainability initiative for the production of vegetal soaps, fats, and oils. BIU became a regular Natura supplier by adhering to the same requirements and criteria as all other suppliers. Therefore, BIU competes with other companies to provide raw materials to the Cajamar Industrial Unit of Natura. Since its inception, BIU has sought to: I meet the demand for vegetal soaps, mass, and oils for various Natura cosmetic product lines; (ii) develop processes and equipment for

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[35] It was the third factor that promoted the eco-industrial development process in Benevides (GRAPH 3).

vegetable oil extraction production; and (iii) organize the vegetable oil supply chain with the participation of cooperatives owned and operated by farm workers.

Since 2003, the lack of a Natura management team in the geo-economic region of the Amazon and key local partners has posed the greatest obstacle to the achievement of this final objective. Nonetheless, family-farming-based vegetable oil supply chains were crucial to the success of a number of Natura departments, including R&D, marketing, procurement, and manufacturing. In order to develop vegetable oil supply chains based on family farming, the BIU's Office of Eco-Relationship Management (OERM) was established. Therefore, OERM assumed responsibility for managing the eco-relationships between Natura and all rural communities in the GRA, not only to facilitate the supply of Brazilian biodiversity products but also to ensure consistency over time.

### 3.2 The office of eco-relationships management

The office of eco-relationships management can be regarded as the fourth factor for eco-industrial development in Benevides. OERM was created with the aim of ensuring the supply of biodiversity products for BIU through sustainable relationships with farm workers and partners. To achieve this goal, in 2007, the OERM manager held several meetings and workshops at family farming cooperatives to explain Natura's interests, its project in the geo-economic region of the Amazon, its growth plans, its plans for the future, and the importance of farm workers, labor unions, and NGOs to the BIU.

As a result of these actions, the OERM manager established partnerships with farm workers' unions and non-governmental organizations (NGOs). This allowed OERM to set about developing supply chains for biodiversity products. The purpose of the OERM manager was to integrate farm workers into BIU as suppliers.

To fulfill this purpose, OERM had to develop and implement a method for cluster development[36] known as "on-site technical consultancy." The method consists of a series of meetings to foster engagement in farm workers and provide training on cooperative management, including equitably sharing benefits, financial management, tax payments, work security, and forest management. During meetings, OERM makes donations of personal protection equipment, such as goggles, face shields, helmets, gloves, and boots.

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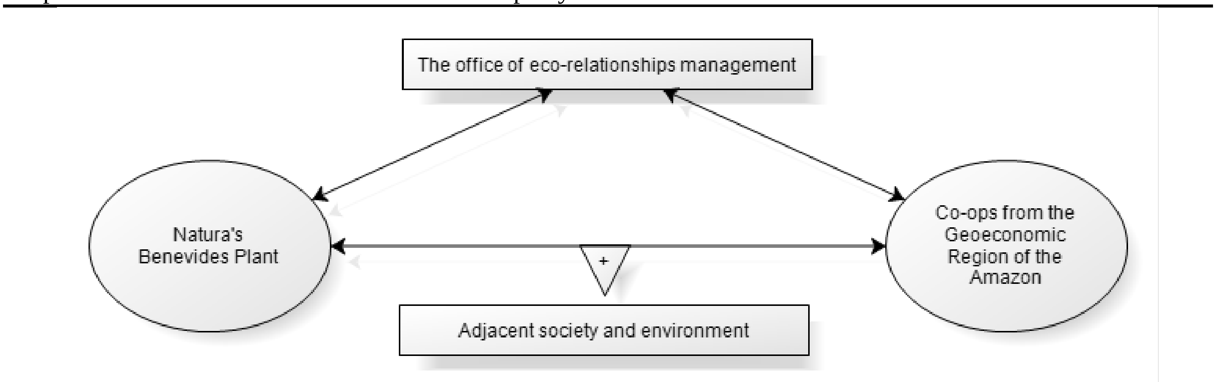
[36] By method for cluster development, I mean the procedures that create a sense of being a business partner in the group of farm workers. It enabled the development of eco-relationships.

The application of this method required the OERM team to travel along the geo-economic region of the Amazon, visiting family farming cooperatives and their members' residences. It built trusting relationships among farm workers, cooperatives, and Natura. In addition, it contributed to dismantling a labor exploitation model that has existed for years throughout the Amazon region.

By contacting family farming cooperatives according to the on-site technical consultancy method, OERM staff promotes the harmonious integration of farm workers into the BIU manufacturing model. On the other hand, based on the information collected over meetings, OERM integrates BIU into the harvesting model of cooperatives. Therefore, OERM has an intermediary role, as shown in Graph 4. Its function is to enable win-win relationships among BIU and cooperatives. These connections are called eco-relationships due to their capacity to create positive externalities for society and natural ecosystems.

Graph 4 – The intermediation of eco-relationships by OERM




Source: Adapted by the author from NVivo 10.

In addition to employing on-site technical consultancy, OERM monitors the supply of various biodiversity products using metrics. This procedure enables OERM personnel to identify the specific characteristics and demands of each participant in the supply chain, such as the production limits and seasonality of each plant species. This monitoring procedure also enables OERM staff to gain a comprehensive understanding of the complex condition of the GRA for eco-relationship planning. There are numerous contexts within the GRA, including dry land regions with an agricultural culture; regions comprised of immigrants from the South, Southeast, and Midwest regions of Brazil; regions consisting of immigrants from the northern region of Brazil; and regions largely composed of indigenous communities from the Amazon region.

### *3.2.1 OERM's management approach*

To cope with challenges associated with the intermediation of eco-relationships, OERM's team has developed a management tool called the "Model for Commitment" (MC). This is a set of values, principles, and steps for balancing profitability and sustainability in the relationships between BIU, family farming cooperatives, the surrounding community, and the environment.

The Model of Commitment is founded on a quadruple bottom line, which comprises financial, social, environmental, and human considerations. In terms of finances, MC stipulates that relationships between organizations must be based on mutual success and greater investment autonomy. In order to foster a higher level of integration between members, MC defends cultural diversity on a social level. Concerning environmental issues, MC asserts that ecosystems are directly dependent on managers' respect for biodiversity and considerations of future impacts from productive and commercial activities. Regarding the quality of human relations, which MC defines as interactions between managers, employees, customers, suppliers, and government officials, MC asserts that they must be founded on transparency, dialogue, respect, and trust.

By translating the principles, values, and processes of the Model of Commitment into objectives, metrics, targets, initiatives, and budgets, a process involving planning, implementation, evaluation, and adaptation, the Office of Eco-Relationships Management has fostered a business environment characterized by trust, openness to dialogue, and transparency. This context was produced and reproduced by the interactions between the BIU and family farming cooperatives, as well as the relationships established between farm workers. According to the manager of OERM, this business environment permitted:

a) BIU earns loyalty and retains customers, who, in turn, have respect for BIU;
b) BIU achieves its objectives through the dedication of its employees, who in turn work for the BIU's growth;
c) BIU preserves biodiversity, which in turn provides inputs for BIU;
d) BIU is shared with farm workers, who, in turn, teach BIU about biodiversity;
e) BIU generates revenue for the government, which, in turn, seeks to create a partnership with the BIU.

On the basis of OERM's results, it can be assumed that the Model of Commitment served as a method for clustering organizations. Importantly, MC supported the establishment of a closed loop among facilities located in the GRA, analogous to the closed cycle of materials, nutrients, and energy in a natural ecosystem. This demonstrates that OERM managers actively implemented an eco-industrial development process in the GRA, which culminated in 2008 with the formation of the Benevides Industrial Ecosystem. Therefore, the management approach of OERM appears suitable for stimulating eco-industrial development. In the subsequent description of BIE, this property becomes more apparent and understandable.

### 3.3 Description of the Benevides Industrial Ecosystem

The Benevides Industrial Ecosystem is an environmentally friendly business system organized around the processing of oilseeds for cosmetics production. Its primary components are Natura's Benevides Industrial Unit and cooperatives owned and run by farm workers. BIE is the result of a strategic decision made by Natura managers to establish a new model of production and trade that is beneficial to society and natural ecosystems. They decided to maintain the integrity of the supply chain for vegetable fats and oils by using industrial ecology principles to protect biodiversity in the GRA, where the plant species used to make cosmetics are found.

According to the most recent data made available to stakeholders, BIE encompasses 16 Brazilian counties in four states and involves directly and indirectly 1,536 rural families in the production of a variety of biodiversity products, like as açaí, andiroba, cupuacu, murumuru, cocoa, and passion fruit. At least three individuals comprise each rural family in the Benevides Industrial Ecosystem. Thus, roughly 4,600 people can benefit from this initiative.

BIU is an essential component of the Benevides Industrial Ecosystem. Even though it has a significant impact on the industrial ecosystem as a whole, BIU serves as a facilitator and not the owner. The BIU, which provides vegetable soaps, mass, and oil to the Cajamar Industrial Unit of Natura, stimulates the creation of a number of new businesses within the BIE through the office of eco-relationship management. The majority of businesses within the Benevides Industrial Ecosystem are family farming cooperatives that harvest fruits from the Amazon rainforest of Brazil. Consequently, they are small business organizations, and their influence on BIE is minimal.

There are two notable industrial symbioses within the Benevides Industrial Ecosystem. The first entails the supply of by-products, such as oilseeds[37], by family farming

[37] The seeds of passion fruit and cupuaçu are transformed into vegetable fat and oil for use in cosmetics. In this instance, BIU processes what would ordinarily become compost.

cooperatives to BIU, which manufactures vegetable soap mass and oil. The second consists of BIU supplying by-products to Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC) and waste to a few manufacturers of inexpensive soap. To mitigate the effects of market fluctuations on industrial symbioses, BIU forecasts its demand for by-products over a three-year period. During this timespan, BIU may adjust the demand for oilseeds once per year in response to fluctuations in the market for Natura products. In all cases, however, BIU guarantees the purchase of a minimum percentage of the oilseeds initially agreed upon and does not require supply exclusivity, allowing family farming cooperatives to sell any surpluses to any company.

Regarding the governance model adopted at the BIE level, the office of eco-relationship management acts as the primary manager and employs a persuasion-based management style. Its role is limited to the promotion, development, and maintenance of industrial symbioses within the BIE, allowing industrial ecosystem components to determine their own eco-relationships. OERM hosts events to increase awareness of industrial symbiosis and its benefits to business organizations, society, and natural ecosystems in order to promote industrial ecology in the geo-economic region of the Amazon. To make IS possible, OERM offers new entrants to the Benevides Industrial Ecosystem financial assistance, training, personal protective equipment, and harvesting equipment. Industrial symbioses are maintained through on-site technical consulting, monitoring of the supply chain, and equitable distribution of benefits.

### *3.3.1 The goals of the Benevides Industrial Ecosystem*

Natura considers ecosystem services and cultural heritage to be highly valuable assets, and their use must always involve efforts to preserve and protect them for future generations. Consequently, the objectives of the Benevides Industrial Ecosystem are as follows: (i) promoting conservation and sustainable use of biodiversity; (ii) valuing ecosystems and the natural heritage of the regions in which it is located; and (iii) improving the socioeconomic conditions of rural communities.

As reported by the manager of the OERM, the human factor in biodiversity conservation is crucial. Rural communities within the GRA are negatively impacted by poor socioeconomic conditions, which encourage individuals to pursue their own short-term interests. Unemployment, social inequality, housing shortages, violence, environmental crimes, geographical isolation, and a lack of access to essential public services facilitate illegal forest harvesting and related commerce. As a result, ecosystem services are degraded or eliminated. Therefore, the OERM manager recognizes that farm workers must be compensated fairly and equitably within BIE. Integration of farm workers into the Benevides Industrial Ecosystem is a top priority for OERM given their contribution to the conservation of ecosystems that regulate and maintain Brazilian biodiversity.

### *3.3.2 The meaning of the industrial ecosystem for stakeholders*

According to interviewees, the Benevides Industrial Ecosystem is a highly recyclable, sustainable production chain. In this eco-friendly business system, family farming cooperatives' by-products are utilized by BIU, which in turn provides its by-products and wastes to other organizations. Managers of the BIU realized over time that the concept of industrial symbiosis could extend beyond the standard model limited to the exchange of by-products and wastes. Consequently, BIE components begin to share facilities, raw materials, knowledge, and brand equity. In this sense, BIE has evolved into a mechanism for optimizing the use of all available resources throughout the entire production chain.

Staff at OERM acknowledged that industrial symbioses added value to the Benevides Industrial Unit and family farming cooperatives. According to the principal manager of the BIU, using oilseeds from family farming cooperatives provided benefits such as traceability, a high degree of predictability, reliable supply, technical quality of raw material, and a competitive price. Given its contribution to providing social inclusion for farm worker families in the Amazon Geoeconomic Region, BIE is essential for building brand equity for Natura products. Moreover, BIE contributes to delivering value to Natura's consumers, as the cosmetics made from family farming cooperatives' by-products can keep their skin in good condition.

As said by farm workers, their contact with Natura at BIE brought several benefits: business partnerships; monetization of the harvesting of forest products; introduction of new biodiversity products to the market; new customers; sales of by-products; support for oil quality assessment; technical consulting; training; research for improving oilseed production and quality; incentives for oil extraction; provision of personal protection equipment; and a collective bargaining agreement for price definition.

BIE's local partners, including EMBRAPA, EMATERCE, CEPLAC, and FASE, have been active in the Amazon region for many years. Consequently, these organizations have a comprehensive understanding of the socioeconomic and environmental challenges that the population of the Brazilian Amazon needs to face. Local partners' staff has a favorable opinion of

Natura due to BIE's contribution to an increase in family farm income in the region. They demonstrate a willingness to contribute to the eco-industrial development projects of Natura. According to their accounts, the major strengths of BIE are as follows: increased forest product trade, improved working conditions, advancements in education, opportunities for income generation, the highest-quality products, the opening of new markets, and the conservation of ecosystems.

### *3.3.3 Primary components*

To achieve BIE objectives, the office of eco-relationship management selects organizations that are beneficial to both present and future generations. OERM employs not only technical and quality criteria but also social and environmental indicators for this purpose. Consequently, OERM retains as BIE members only those organizations with the greatest potential to conserve natural resources while also generating social benefits. OERM selects organizations, preferably from rural communities, conservation units for sustainable use, and groups of farm workers to supply biodiversity products such as oilseeds. This preference is contingent on organizations' cost and supply capacity.

Despite their great potential to provide social and environmental benefits, the majority of these organizations lack the capacity to meet the demands of large-scale production. For this reason, OERM prioritizes organizations that adopt legally binding governance processes to ensure the legitimacy of their leaders. Because of this rule, farm workers know that they have to be part of worker cooperatives or associations in order to join BIE.

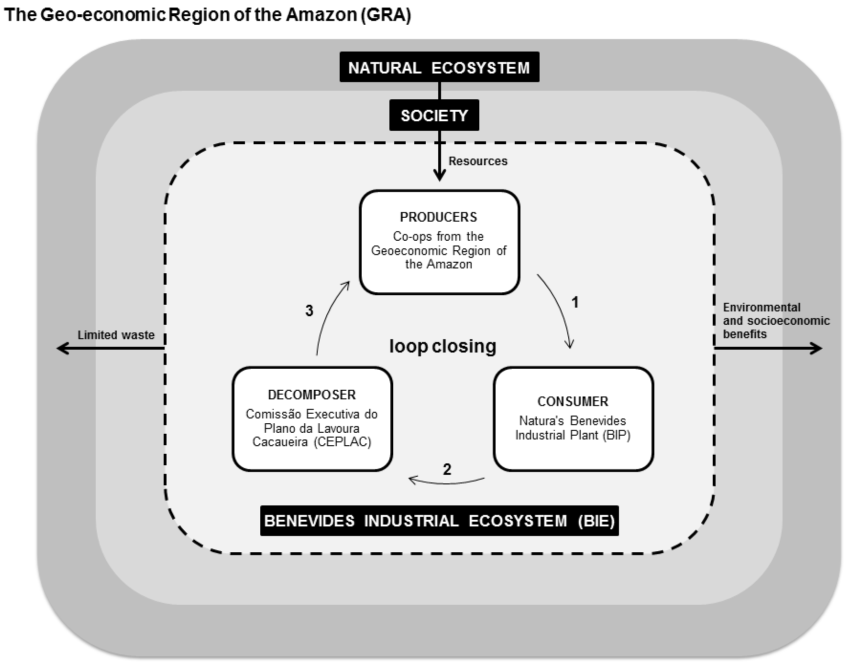
### *3.3.4 Primary components' functions*

For improved planning, OERM categorizes BIE primary components based on their capacity to promote three benefits: (i) biodiversity conservation; (ii) sustainable development; and (iii) positive social impact. This classification yielded three categories, each with a unique capacity to provide these benefits. The first group comprises traditional communities, conservation units for sustainable use, and family farming cooperatives. They are identified as organizations with greater capacity to promote social and environmental change [38]. The second

[38] The special characteristics that give members of the first group a high potential for promoting social and environmental developments in general are associated with: the territorial scope of their operations; the number of people directly or indirectly involved in the harvesting of forest products; the capacity to reproduce cultural knowledge that supports biodiversity conservation; and the capacity to generate social technologies that can be replicated in other similar locations.

group includes public universities, research organizations, individual farmers, non-governmental organizations (NGOs), and public-interest civil society organizations (OSCIPs). The third group consists of rural entrepreneurs, private universities, businesses, and units of Natura.

Figure 4 – Benevides Industrial Ecosystem




Source: Adapted by the author.

As depicted in Figure 4, the members of these three groups close a loop[39] in the Amazon’s geoeconomic region. This operational process resembles the material, nutrient, and energy cycles inherent to natural ecosystems. Therefore, the interaction between a community of facilities and businesses, their society, and the environment fostered by Natura in the GRA can be considered an industrial ecosystem. It also indicates that Natura managers have applied the biological analogy at the level of facilities to organize BIE, utilizing industrial ecology concepts regarding the flow of materials through industrial symbiosis.

The Benevides Industrial Ecosystem was created by applying biomimicry to the design of business networks. BIE imitates the following features found in a natural ecosystem: primary production, decomposition, nutrient cycling, trophic dynamics, homeostasis, and the concept of ecosystem goods and services. This business network model inspired by nature enabled BIE components to increase production efficiency while maintaining a profitable agricultural trade and a sustainable oilseed supply chain.

[39] Loop closure is the closed cycle of materials, nutrients, and energy in natural ecosystems (LIFSET; GRAEDEL, 2002).

According to Figure 4, family farming cooperatives in the frozen fruit pulp sector in the GRA[40] mimic primary production. As producers, these cooperatives are responsible for harvesting fruits in the nearby natural ecosystems, a process that seems analogous to the production of organic matter. Farm workers employ traditional harvesting techniques learned from the society or culture surrounding them. The variety of oilseeds, i.e., organic matter, supplied by family farming cooperatives supports directly or indirectly the production and trade operationalized by all BIE components.

As fruit pulp suppliers for the food and beverage industry in the GRA, the family farming cooperatives cultivate biodiversity products such as açaí, passion fruit, cupuaçu, and cocoa. These cooperatives generate by-products such as seeds and almonds from the production of fruit pulp. According to the first industrial symbiosis depicted in Figure 5 on the next page, the Benevides Industrial Unit of Natura is the primary consumer of these by-products generated by family farming cooperatives and transforms them into vegetable fats and oils. These raw materials are sold to Natura's Cajamar Industrial Unit, the secondary consumer, which then incorporates them into its products, including the Natura Ekos line of cosmetics.

In the second industrial symbiosis, depicted in Figures 4 and 5, BIU extracts vegetable fats and oils by pressing oilseeds and produces a by-product known as "seed oil cake." This material is given to CEPLAC, an organization that acts as a decomposer. Using "seed oil cake" obtained from BIU, CEPLAC produces an organic fertilizer that promotes the growth of cocoa seedlings in a germplasm bank. CEPLAC cultivates high-quality cocoa seedlings with organic fertilizer derived from BIU byproducts and distributes them for free to family farming cooperatives. By closing the loop, CEPLAC ensures BIE's environmentally sustainable operations. This industrial symbiosis does not involve any economic transactions comparable to those between BIU and family farming cooperatives; however, it does generate the three benefits sought by OERM.

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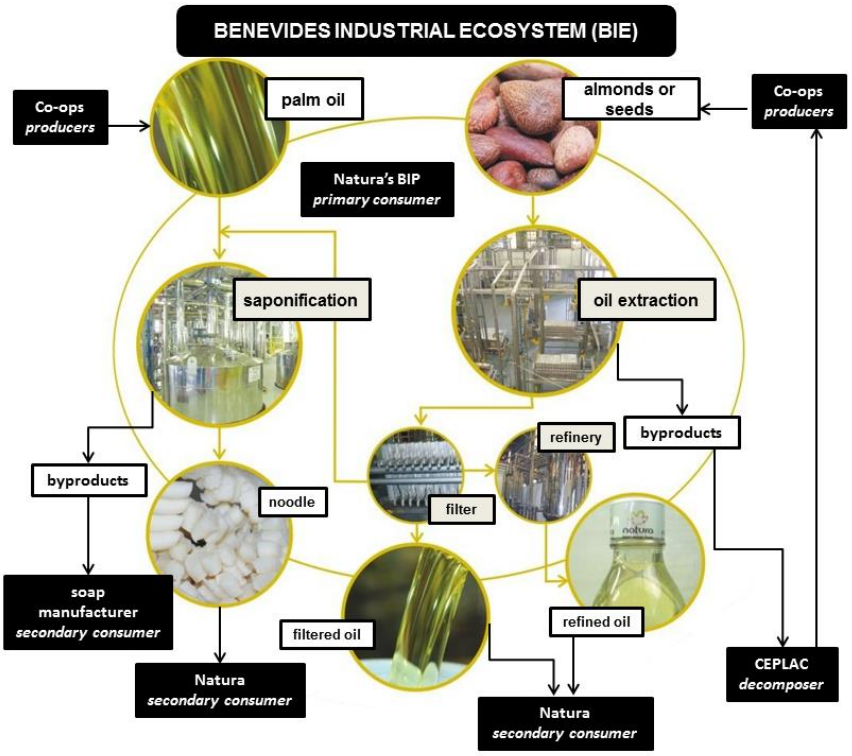
[40] The family farming cooperatives involved in the Benevides Industrial Ecosystem are: COFRUTA, CAEPIM, ASSOCIAÇÃO JAUARI, CART, COPOAM, COOMAR, CAMTA, COAPROCOR, COOPCAO, COPOPS, COPOTRAM, COPOXIM, COPOBOM, COPAVAM, CAMTAUA, and FLORABRASIL.

Figure 5 – Industrial symbioses identified within BIE




Source: Adapted by the author.

Figure 5 illustrates an extra industrial symbiosis in addition to those previously discussed. It is directly related to the BIU's saponification process, which involves the transformation of oilseed fat and oil into vegetable soap mass. Due to eventual saponification failures, the BIU frequently produces soap masses that do not meet the quality standards specified by the Cajamar Industrial Unit of Natura. Since Natura's Cajamar Industrial Unit does not purchase non-standard soap mass, it becomes a production loss. BIU managers have decided to sell non-standard soap mass to a manufacturer of cheap bar soaps in order to transform this problem into a business opportunity with social, economic, and environmental benefits. BIU has developed a further industrial symbiosis as an alternative to incineration or discarding the waste. In this agreement, BIU sells non-standard soap mass as waste for a much lower price than it should.

### *3.3.5 Secondary components and their functions*

The boundaries of the Benevides Industrial Ecosystem are loosely defined, as Figure 4 illustrates, and subject to change as new businesses enter and exit. In addition, the boundaries are left open so that BIE components can learn a set of beliefs, practices, learned behaviors, and moral values from their communities and benefit from ecosystem services offered by the natural environment. Therefore, the Benevides Industrial Ecosystem, the society surrounding it, and the natural ecosystems in its vicinity interact closely and are frequently interdependent.

Society and the surrounding environment are secondary components of the Benevides Industrial Ecosystem since they are absolutely indispensable to the functioning of BIE components. Thanks to the utilization of beliefs, practices, learned behaviors, and moral values from near and far communities, as well as ecosystem services from the nearby natural environment, BIE components capitalize on economic opportunities fostered by eco-industrial development. They use the situation for sustainable development to obtain business ideas, prospects, proposals, and other chances linked with the leasing, acquisition, exploration, production, gathering, or sale of oilseeds and associated by-products and waste. For instance, the biodiversity products provided by ecosystem services found in the GRA are harvested and processed using technology created by nearby and distant communities, whose members also contribute to the creation of market demand for Natura's cosmetics.

### *3.3.6 The eco-industrial development of the BIE*

BIU contributed to the creation of the Benevides Industrial Ecosystem through its office of eco-relationships management to supplement its core business, which consists of supplying vegetable soap mass and oil to the Cajamar Industrial Unit of Natura. In terms of methodology, the BIE is the result of OERM's application of the Model of Commitment to ensure the socioeconomic and environmental sustainability of BIU's production and trade.

Accordingly, the application of the Model of Commitment by OERM was a process of managing eco-industrial development[41]. It consisted of making policies and implementing practices that could increase the competitiveness of BIE components while simultaneously advancing economic, social, and environmental conditions in the communities in which they operate. It was a dynamic process of continuous improvement that established new objectives every year. Despite the constant adaptation of policies and operating procedures, the following values continue to shape OERM's management system: consultation, communication, partnerships, transparency, dialogue, and commitment.

[41] It will be analyzed in Chapters 4 and 5 through the development of the proposed theoretical framework.

In the following two sections, OERM's intended policies and green innovation practices to foster the eco-industrial development of BIE will be outlined.

*3.3.6.1 Policies towards eco-industrial development*

Through industrial symbioses, the Benevides Industrial Unit of Natura facilitated the harmonious integration of other BIE components into its manufacturing model, as well as its own incorporation into their production operations. To effectively foster integration, BIU's planning of by-product demand has taken into account the specific characteristics, gaps, and requirements of other BIE members. Also, supply contracts considered how much each family farming cooperative could produce and when each plant species should be cropped.

In order to minimize the impact of market fluctuations on the lives and incomes of farm workers, BIU managers typically estimate the demand for by-products over a three-year horizon[42]. During this period, BIU is permitted to adjust the volume of supply once per year in response to fluctuations in demand for Natura's products. Nonetheless, BIU guarantees the purchase of a minimum proportion of the agreed-upon by-products. Additionally, it does not mandate an exclusive supply, allowing cooperatives to negotiate their surpluses.

The prices paid for family farming cooperatives' by-products are always negotiated directly with them. The prices adequately compensate their cost structure and allow for a profit margin. In this instance, costs encompass all expenses associated with environmentally friendly operations. In addition, BIU always encourages their suppliers to improve their cost structure so that their profit margins for the same raw materials can be in line with the market price.

As a key organization within BIE, Natura's Benevides Industrial Unit requires the traceability of all family farming cooperatives' by-products that it uses in the manufacture of vegetable soap mass, fat, and oil to ensure their origin and sustainable forest management, and hence to minimize operational risks. This assurance is unconditional and must be given by family farming cooperatives, as well as being verifiable through an external audit. Assessments are conducted in rural communities where BIU's activities have the greatest impact.

According to BIU managers, the positive results of BIE are contingent on the quality of its industrial symbioses. In addition to establishing channels of communication, the BIU aims to ensure ethical and transparent partnerships with all parties with whom it interacts

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[42] Contracts that cover a period of less than three years can only be signed by BIU occasionally, when necessary to supplement the capacity of a regular supplier. In any case, BIU always gets its by-products from family farming cooperatives that have been harvesting the oilseeds they need for a long time and are very good at it.

within the BIE. Due to the complexity of industrial symbioses and the high level of commitment that BIU wants to build with other BIE members, partnerships with family farming cooperatives must be approved by a specialist committee. The candidates for a position as a member of BIE must have attained positive results on the metrics used to evaluate existing industrial symbioses.

*3.3.6.2 Green innovation practices for eco-industrial development*

To reach the pro-environmental perceptions, attitudes, and behaviors of consumers, Natura reconceived its products and markets, as depicted in Graph 5, and redefined productivity throughout the entire value chain. These three green innovation practices comprise a platform anchored in the following principles: eco-friendly consumers as a new target; the use of biodiversity products for research and development; and the application of green technologies. Such a platform can be regarded as a solid foundation for the eco-industrial development of BIE, as it has created industrial symbiosis opportunities[43] in the Amazon's geoeconomic region. It is worth mentioning that the business of oilseeds (by-products), which combine capital, expertise, technologies, and processes for industrial symbioses, started as a response to green innovations implemented by Natura. Accordingly, this means they triggered the formation of the industrial ecosystem in Benevides and generated positive externalities, as will be discussed further.

Natura needed to create economic stimuli, such as the price appreciation of by-products, and to share procedural knowledge equitably in order to obtain biodiversity products from family farming cooperatives located in the GRA. To ensure that seeds and almonds were harvested using green technologies, Natura invented new forest management techniques and harvesting equipment and then distributed them with farm workers. By putting into practice an intervention on "safety and health at work" and a program on "forest management certification," Natura improved the human and organizational capital of family farming cooperatives. These programs facilitated the eco-industrial development of BIE by allowing industrial symbioses between Natura and family farming cooperatives and a shared commitment to sustainability.

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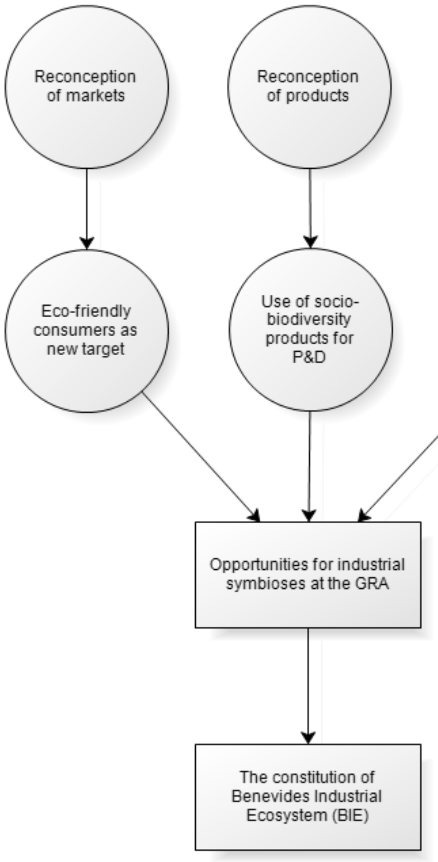
[43] By industrial symbiosis opportunities, I refer to the buying or selling of by-products that enables a business to achieve cost reduction, revenue growth, or business expansion while generating positive externalities.

Graph 5 – Green innovation practices for BIE eco-industrial development




Source: Adapted by the author from NVivo 10.

### *3.3.7 Dynamic equilibrium adjustment and regulation in the BIE*

Similar to dynamic equilibrium adjustment and regulation mechanisms in natural ecosystems, corporate social responsibility (CSR) instruments enable the Benevides Industrial Ecosystem to reach “homeostasis.” Instruments for CSR serve as homeostatic responses to threats posed by BIE’s surrounding society or environment, whose problems can disturb its normal condition. This feedback phenomenon occurs as a result of socially interdependent investments in BIE’s secondary components, which ensure its primary components’ production cycles. Considering that consistent production cycles depend on a healthy society and a conserved environment, the OERM team’s socially responsible investment portfolio seeks to be successful in mitigating negative effects from the medium surrounding the Benevides Industrial Ecosystem.

BIE’s operations may be disrupted by social and environmental problems in the Amazon geoeconomic region. Regional issues about education, health care, and equal opportunity can negatively impact workforce productivity. Inadequate working conditions for farm workers not only deter them from committing to the use of methods that do not harm the environment but also raise the internal costs of accidents. The inefficient use of land, water, energy, and other natural resources by farm workers can reduce the productivity of businesses. Bad local government can hinder innovation. Weak regulatory standards can leave both consumers and farm workers vulnerable to exploitation. All of these social and environmental harms can result in internal costs for BIE's primary components, rendering their businesses unprofitable.

In light of the threats posed by the potential increase in internal costs, the Benevides Industrial Unit of Natura assumed local government responsibilities associated with the BIE. Despite the fact that the aforementioned social issues were matters of public policy, BIU managers decided to address some of them. The OERM team identified the points of intersection between BIE and social and environmental problems in the GRA with the assistance of FASE. Then, they developed instruments for CSR aimed at addressing social issues at the intersection of BIE, society, and the environment. These instruments for CSR are operationally translated into socially responsible investments in BIE's secondary components for the purpose of balancing and maintaining industrial symbioses. Despite serving a purely commercial purpose, these "homeostatic" responses generate positive externalities.

The OERM team oversees two types of investments for "homeostasis" regulation: investments for socioeconomic benefits and investments for environmental benefits (FIGURE 4). These benefits appear to be analogous to the concept of ecosystem services; once they make BIE possible, they are indispensable for his survival. Socioeconomic benefits are advantages from investments made in the demographic, economic, sociopolitical, scientific, technological, cultural, and religious dimensions of nearby communities. They have an indirect impact on the functioning of BIE. As an example, the OERM has provided farm workers with remedial training to compensate for their educational deficiencies. Environmental benefits are advantages from investments in changes in local land use and cover, the introduction or eradication of species, adaptation and use of technology, external inputs, harvesting and resource consumption, climate change, and natural, physical, and biological drivers. They have a direct impact on BIE's operations. As an illustration, OERM has promoted the sustainable harvesting of murumuru by valuing and increasing BIU's consumption of this almond. As a result of this initiative, deforestation has been reduced.

The policies that guide investments for socioeconomic and environmental benefits in order to regulate "homeostasis" within the Benevides Industrial Ecosystem will be presented in the following two sections.

*3.3.7.1 Investment policy for socioeconomic and environmental benefits*

Due to the use of native plant species from Brazilian biomes and the application of traditional knowledge in the cultivation and harvesting, the OERM must create socioeconomic and environmental benefits and deliver them equitably to the family farming cooperatives with which Natura interacts. The process of creation and delivery of benefits have to comply with Brazilian laws governing the use of the country's biological diversity. In addition, it is managed to perform without direct compensation whenever possible. Following these guidelines, OERM applies the process of creation and delivery of benefits by financing initiatives that contribute to the development of the Amazon's geoeconomic region. These initiatives should address the issues listed below:

a) environmental conservation;
b) sustainable use of natural resources;
c) cultural appreciation;
d) fair trade;
e) productive chain strengthening;
f) farm workers' cooperatives strengthening;
g) social mobility;
h) employment and income generation;
i) sharing of educational, scientific and technological resources.

The Benevides Industrial Unit of Natura promotes the conservation of ecosystems containing plant species used in its products' manufacture. To accomplish this, BIU's managers determined that all plant species would be sourced from sustainable crop production. In practice, the first contact with particular plant species or substances extracted from them for the purposes of research, bioprospecting, or technological development is always governed by Brazilian law. A further step in the BIU's procedure is to source plant species, preferably from regions where farm workers employ crop harvesting techniques and agroecological management practices adopted in biodynamic agriculture. In addition, the OERM team conducts research and develops new harvesting techniques and equipment, which they then share with farm workers. Through these initiatives, farm workers make more efficient use of land, water, energy, and other natural resources. As a result, the negative environmental effects of BIE's operations are mitigated.

Following the previously mentioned investment policies for socioeconomic and environmental benefits, the office of eco-relationship management has implemented murumuru harvesting.

3.3.7.2.1 A case of homeostatic response: the introduction of murumuru harvesting

Murumuru is a palm tree species that grows wild in the forests of the state of Pará, especially along rivers and flooded areas within dense or semi-open forest formations. This palm tree species can reach 10 meters in height. Its fruit is a reddish coconut when it is ripe. Its core contains a hard almond, which is surrounded by a yellowish pulp that is edible and slightly sweet. This almond is very oily and also edible (FIGURE 6). Another characteristic of this palm tree is the fact that its bunches of coconuts grow facing up. Murumuru grows together with other tree species, such as andiroba, ucuúba, and açaí.

Figure 6 – The almonds of murumuru

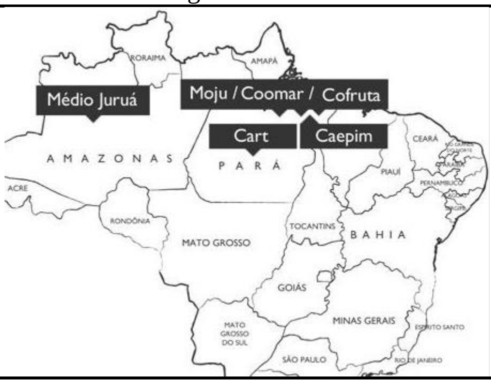
Source: Adapted by the author from Natura Ekos's website.

When BIU began operations in the state of Pará, açaí was the most important source of income for rural communities. The second were andiroba and ucuúba, whose stems were illegally sold to broomstick manufacturers by rural communities. Without a commercial purpose or monetary value, murumuru was merely a thorny palm that prevented farm workers from harvesting other tree species. As a result, every July, when the weather turned dry, farm workers set fire to the murumuru grove. When a tree was not burned, it was felled. Due to this irregular deforestation practice, murumuru was on the verge of becoming a palm species added to a list of endangered species. In certain regions of the Brazilian state of Pará, the murumuru was nearly extinct.

Before Benevides Industrial Unit was founded in 2007, a Natura scientist conducted bioprospecting in the forests of Pará and made an initial contact with murumuru. After a series of laboratory tests, the scientist discovered that the oil extracted from murumuru almonds had a highly moisturizing effect. In light of the fact that emollient properties impart shine, hydration, and protection to hair, the scientist determined that murumuru almonds were suitable for use in cosmetics. As a result, the scientific discovery of murumuru created a market for it as well as a means to reduce social and environmental harm in the Amazon region.

When the Benevides Industrial Unit was established in 2007, the first challenge for OERM staff was to encourage the harvesting of murumuru because farm workers did not believe that this almond was an agricultural product. OERM strategies consisted of: (i) holding seminars on murumuru and its use in cosmetics production; (ii) developing methods and techniques of murumuru harvesting; (iii) sharing this knowledge with farm workers through the use of booklets and on-site technical consultation; and (iv) supplying harvesting equipment. When this initiative was launched by OERM, only 35 rural families were harvesting murumuru. There are currently six family farming cooperatives in six counties, with approximately 600 rural families (FIGURE 7).

Figure 7 – The co-ops responsible for the harvesting of murumuru in the GRA



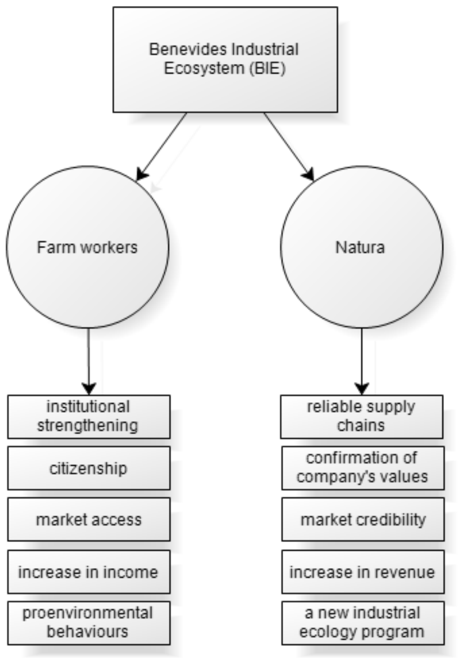

Source: Adapted by the author from Natura Ekos’s website.

This initiative generated justifications for environmental protection and sustainable use of natural resources among rural families involved. Since they began selling almonds from Murumuru, farm workers have stopped setting fire to the orchard and cutting down trees. As a result, the number of forest fires decreased dramatically. The adoption of fair trade practices by BIU increased the income of farm workers. Moreover, the sharing of methods and techniques for harvesting murumuru improved the crop yield of cooperatives.

## 3.4 The effects of BIE on its components

The Benevides Industrial Ecosystem can provide its primary components with economic, social, and environmental benefits. These effects become more apparent when analyzing the outcomes achieved by the BIE's principal members: farm workers and Natura (GRAPH 6).

Graph 6 – The effects of BIE on its main components




Source: Adapted by the author from NVivo 10.

### *3.4.1 Farm workers*

The social benefits provided by BIE are associated with the institutional strengthening of family farming cooperatives in the Amazon region. Their participation in the BIE allowed them to gain access to the market for biodiversity products and financial, technological, and educational resources. These factors attracted a greater number of farm workers to family farming cooperatives in the GRA, resulting in an increase in cooperative membership and member participation at assemblies.

In conjunction with the institutional strengthening of family farming cooperatives, BIE promoted citizenship in rural communities that supply Natura with biodiversity products. The majority of rural families in the GRA are deprived of various rights and opportunities that are normally available to all citizens. Given that this circumstance has negative effects on the functioning of an industrial ecosystem, OERM needed to mitigate social exclusion in the region. Throughout the institutional strengthening process of family farming cooperatives, OERM hosted events to raise awareness of the significance of registering an organization and paying taxes in order to claim formerly essential public services.

Families of farmworkers reached fair agreements with BIU and other companies because their cooperatives were registered and efficiently organized. Consequently, their income increased substantially. The annual household income in the Amazon geoeconomic region is between $1,500 and $1,700 Brazilian Reais, according to the OERM manager. Some farmworker families within the Benevides Industrial Ecosystem receive between $1,000 and $1,800 Brazilian Reais for a three-month supply of biodiversity products. Once their income had increased, they could afford a higher standard of living. According to interviewees, after the establishment of BIE in 2007, they improved their dwellings and purchased domestic appliances and power generators. And hence, they were able to store fresh meat, fish, and milk, which benefited their health.

Since the formation of BIE, rural communities in the GRA have become increasingly concerned with environmental issues. As a result of environmental conservation and sustainable use of natural resources trainings held by OERM, farm workers understood the negative effects of indiscriminate forest clearance on oilseed harvesting and trade. Because of this, they started to preserve the natural ecosystems where they work.

### *3.4.2 Natura*

According to BIU managers, the Benevides Industrial Ecosystem strengthened the reliability of the supply chains for biodiversity products. Prior to the establishment of BIE, the availability of oilseeds was unreliable. As a consequence, managers could not make effective sales plans for Natura products. Currently, if BIU requires a specific quantity of oilseeds, farm worker cooperatives can fulfill the request.

As a component of BIE, Benevides Industrial Unit became the business unit within Natura's portfolio with the most environmentally friendly practices. Moreover, BIU's role as a key organization within the Benevides Industrial Ecosystem supports the values and principles of Natura. By operating in the Amazon's geoeconomic region, Natura demonstrates its concern for social issues and biodiversity conservation. In consequence, it gained credibility, resulting in increased sales.

On the basis of the positive effects of BIE on Natura, its managers have recognized that new applications of industrial ecology principles at the company level could further differentiate the company in the marketplace. In order to achieve this objective, the managers of Natura have established “Programa Amazônia,” a new initiative for eco-industrial development in the Amazon’s geo-economic region. Natura will invest up to one billion Brazilian reais in Programa Amazônia until 2020. This program includes (i) increasing the number of rural families involved in the supply chain of Brazilian biodiversity products to up to 12,000; (ii) constructing a knowledge center in Manaus and an eco-industrial park (EIP) in Benevides; and (iii) attracting new environmentally conscious businesses. According to Natura managers, these eco-industrial development initiatives can transform the Amazon region into a major global hub for innovation, technology, and sustainability.

# 4 CATEGORIES, SUBCATEGORIES AND RELATIONAL STATEMENTS

This chapter aims to introduce the categories, subcategories, and relational statements of the theoretical framework for management of eco-industrial development (MEID). To this end, it presents the results of the coding to gather evidence of an eco-industrial development management process within the Benevides Industrial Ecosystem[44]. The analysis of the source materials that provided data for coding is presented in Section 4.1. Section 4.2 then describes how a priori constructs were measured. Based on empirical evidence, Section 4.3 briefly introduces the emerging categories and subcategories that comprise the theoretical framework. In addition, it describes the initiatives of eco-industrial development around the world, where these emerging constructs have also been identified by a review of the literature. Section 4.4 identifies the connections between these constructs, which shaped the theoretical framework.

## 4.1 Analysis of source materials

In order to obtain specific data for questions regarding MEID, the researcher used two groups of source materials: "internal source materials" and "external source materials." Both groups provided knowledge regarding industrial ecosystem management approaches. Importantly, they assisted the researcher in understanding that the same series of evolutionary sequences of action toward eco-industrial development occur at different times and locations around the world.

### *4.1.1 The internal source materials*

The internal source materials include documents and transcripts generated by multiple data collection techniques over the duration of Line of Action 2 (depicted in Table 3). It aimed to collect data on the management approach to EID through semi-structured interviews with managers from Natura and other companies from BIE, document gathering including text, videos, and images, and non-participant observation. Table 7 lists all internal source materials generated during the data collection. It displays the name of the internal source that was coded utilizing a priori constructs from Table 2 by means of constant comparison analysis as described by Strauss and Corbin (2008). In addition, it includes the number of nodes (a priori categories

[44] The summary of coding by source is displayed in Appendix C.

or subcategories) whose definitions were refined by coding internal sources as well as the number of references (words, phrases, or paragraphs) that were coded in order to build evidence.

Table 7 – The summary of internal source material coding

| Type | Name | Nodes | References | Created On | Created By | Modified On | Modified By |
|---|---|---|---|---|---|---|---|
| Document | Document 01 | 101 | 760 | 02/07/2012 2:23 PM | LQ | 12/07/2012 7:56 PM | LQ |
| Document | Document 02 | 56 | 208 | 02/07/2012 2:24 PM | LQ | 12/07/2012 7:40 PM | LQ |
| Document | Document 03 | 28 | 218 | 02/07/2012 2:24 PM | LQ | 12/07/2012 11:30 AM | LQ |
| Document | Document 04 | 46 | 125 | 02/07/2012 2:24 PM | LQ | 12/07/2012 3:37 PM | LQ |
| Transcript | Interview 01 | 78 | 671 | 02/07/2012 5:13 PM | LQ | 12/07/2012 8:02 PM | LQ |
| Transcript | Interview 02 | 94 | 1460 | 03/07/2012 3:46 PM | LQ | 12/07/2012 5:59 PM | LQ |
| Transcript | Interview 03 | 84 | 1303 | 03/07/2012 5:49 PM | LQ | 12/07/2012 8:05 PM | LQ |
| Transcript | Interview 04 | 81 | 1487 | 03/07/2012 5:49 PM | LQ | 12/07/2012 5:52 PM | LQ |
| Transcript | Interview 05 | 56 | 457 | 03/07/2012 5:49 PM | LQ | 12/07/2012 3:16 PM | LQ |
| Transcript | Interview 06 | 81 | 1316 | 03/07/2012 5:49 PM | LQ | 12/07/2012 5:29 PM | LQ |
| Transcript | Interview 07 | 65 | 592 | 03/07/2012 5:49 PM | LQ | 12/07/2012 7:49 PM | LQ |
| Transcript | Interview 08 | 66 | 928 | 03/07/2012 5:49 PM | LQ | 12/07/2012 10:35 PM | LQ |
| Transcript | Interview 09 | 63 | 675 | 03/07/2012 5:49 PM | LQ | 12/07/2012 8:11 PM | LQ |
| Transcript | Interview 10 | 67 | 900 | 03/07/2012 5:49 PM | LQ | 12/07/2012 8:11 PM | LQ |

Source: Adapted by the author from NVivo 10.

Before coding the BIE dataset's documents and interview transcripts to gather evidence of a management process, the researcher had to ensure they had "internal consistency"[45]. This is a critical requirement for a text in the internal source materials in order to facilitate the saturation and generalization of theory. The researcher used NVivo 10 to conduct a cluster analysis based on word similarity in order to examine the presence of this property in all internal sources. As a similarity metric, the Pearson correlation coefficient was used to compare the words contained in the internal sources. Table 8 displays the outcomes of the cluster analysis.

Table 8 – Results of the cluster analysis of the internal source materials

| Source A | Source B | Pearson correlation coefficient |
|---|---|---|
| Document 04 | Document 02 | 0.949651 |
| Document 04 | Document 03 | 0.855769 |
| Document 03 | Document 02 | 0.854838 |
| Interview 07 | Interview 06 | 0.820448 |
| Interview 07 | Interview 04 | 0.819856 |
| Interview 08 | Interview 06 | 0.81681 |
| Interview 08 | Interview 02 | 0.813415 |
| Interview 08 | Interview 07 | 0.799625 |
| Interview 06 | Interview 04 | 0.799193 |
| Interview 05 | Interview 04 | 0.774069 |
| Interview 04 | Interview 03 | 0.770394 |
| Interview 09 | Interview 06 | 0.765397 |
| Interview 09 | Interview 07 | 0.763292 |
| Interview 10 | Interview 09 | 0.763022 |
| Interview 09 | Interview 08 | 0.757415 |
| Interview 09 | Interview 05 | 0.75655 |
| Interview 06 | Interview 03 | 0.755262 |
| Interview 08 | Interview 04 | 0.754543 |
| Interview 06 | Interview 05 | 0.753768 |
| Interview 09 | Interview 04 | 0.752002 |
| Interview 07 | Interview 05 | 0.75002 |
| Document 03 | Document 01 | 0.749757 |
| Document 02 | Document 01 | 0.747347 |
| Interview 09 | Interview 02 | 0.745804 |
| Interview 03 | Interview 02 | 0.744395 |
| Interview 08 | Interview 05 | 0.736993 |
| Interview 04 | Interview 02 | 0.731217 |

[45] By "internal consistency," I refer to the property of a text that enables it to be perceived as a whole and which is dependent on the explicitly established sense relations between words and between the text and the context in which it was produced.

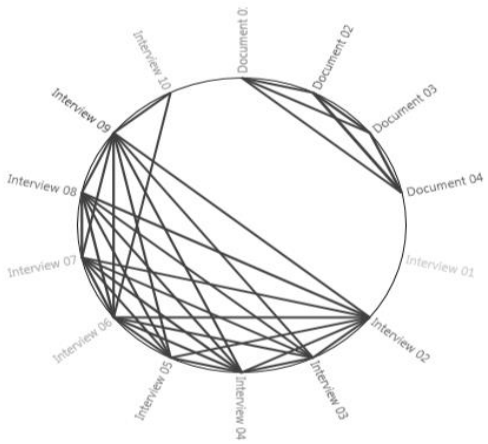
| | | |
|---|---|---|
| Interview 07 | Interview 02 | 0.731216 |
| Interview 09 | Interview 03 | 0.729917 |
| Interview 06 | Interview 02 | 0.729442 |
| Interview 08 | Interview 03 | 0.728723 |
| Interview 05 | Interview 02 | 0.721602 |
| Document 04 | Document 01 | 0.717498 |
| Interview 10 | Interview 06 | 0.709862 |
| Interview 07 | Interview 03 | 0.708262 |
| Interview 05 | Interview 03 | 0.691994 |
| Interview 10 | Interview 07 | 0.691193 |
| Interview 10 | Interview 08 | 0.686417 |
| Interview 10 | Interview 03 | 0.680917 |
| Interview 10 | Interview 02 | 0.668459 |
| Interview 10 | Interview 05 | 0.664635 |
| Interview 10 | Interview 04 | 0.659927 |
| Interview 01 | Document 03 | 0.650682 |
| Interview 01 | Document 04 | 0.63374 |
| Interview 01 | Document 02 | 0.633348 |
| Interview 08 | Interview 01 | 0.630294 |
| Interview 02 | Interview 01 | 0.625959 |
| Interview 06 | Interview 01 | 0.614142 |
| Interview 07 | Interview 01 | 0.600595 |
| Interview 01 | Document 01 | 0.553837 |
| Interview 09 | Interview 01 | 0.550194 |
| Interview 03 | Interview 01 | 0.538932 |
| Interview 05 | Interview 01 | 0.538578 |
| Interview 04 | Interview 01 | 0.53578 |
| Interview 10 | Interview 01 | 0.517109 |
| Interview 05 | Document 03 | 0.327534 |
| Interview 05 | Document 01 | 0.303641 |
| Interview 02 | Document 03 | 0.298497 |
| Interview 03 | Document 03 | 0.283382 |
| Interview 09 | Document 03 | 0.28145 |
| Interview 08 | Document 03 | 0.268277 |
| Interview 06 | Document 03 | 0.258292 |
| Interview 04 | Document 03 | 0.256688 |
| Interview 02 | Document 01 | 0.251462 |
| Interview 09 | Document 01 | 0.242396 |
| Interview 10 | Document 03 | 0.239926 |
| Interview 07 | Document 03 | 0.236967 |
| Interview 03 | Document 01 | 0.236399 |
| Interview 08 | Document 01 | 0.224913 |
| Interview 04 | Document 01 | 0.217882 |
| Interview 06 | Document 01 | 0.20223 |
| Interview 10 | Document 01 | 0.200991 |
| Interview 07 | Document 01 | 0.199392 |
| Interview 05 | Document 02 | 0.185634 |
| Interview 02 | Document 02 | 0.157241 |
| Interview 08 | Document 02 | 0.146581 |
| Interview 09 | Document 02 | 0.144305 |
| Interview 03 | Document 02 | 0.137471 |
| Interview 10 | Document 02 | 0.131147 |
| Interview 04 | Document 02 | 0.125608 |
| Interview 06 | Document 02 | 0.125196 |
| Interview 07 | Document 02 | 0.121005 |
| Interview 05 | Document 04 | 0.116015 |
| Interview 02 | Document 04 | 0.098783 |
| Interview 10 | Document 04 | 0.089959 |
| Interview 03 | Document 04 | 0.087538 |
| Interview 08 | Document 04 | 0.083969 |
| Interview 09 | Document 04 | 0.079097 |
| Interview 06 | Document 04 | 0.076877 |
| Interview 04 | Document 04 | 0.07361 |
| Interview 07 | Document 04 | 0.06997 |

Source: Adapted by the author from NVivo 10.

Table 8 is represented graphically in Graph 7 to illustrate the similarities and differences between the internal sources. Sources with a higher degree of similarity based on the occurrence and frequency of words were clustered together in this cluster analysis diagram. Additionally, connecting lines of varying thickness indicate similarity between items. In Graph 7, thicker lines indicate greater similarity. Conversely, sources with a lesser degree of similarity based on the occurrence and frequency of words were displayed further apart, such as Interview 01.

According to Graph 7, two groups contain words that are highly similar: the first group consists of the documents 01, 02, 03, and 04, and the second group is comprised of the interviews 02, 03, 04, 05, 06, 07, 08, 09, and 10. Note that the strong positive correlation between the majority of interviews, as depicted in Graph 7 and Table 8, allowed for theoretical saturation.

Graph 7 – The internal source materials clustered by word similarity




Source: Adapted by the author from NVivo 10.

### *4.1.2 The external source materials*

External source materials consist of a variety of scientific papers on eco-industrial development or industrial symbiosis chosen over data collection techniques in Line of Action 2 (depicted in Table 3). It aimed to collect data from descriptions of the most pertinent cases of eco-industrial development that were supported by evidence. After selecting scholarly articles, the researcher collected evidence to validate the proposed theoretical framework. To achieve this, he searched for emerging constructs and hypotheses within a dataset of selected scientific papers using coding.

Table 9 lists all the external source materials used for coding. It displays the name of the external source coded based on the constructs discovered during the within-case analysis of the Benevides Industrial Ecosystem. Table 9 also includes the number of nodes (category or subcategory) for which the coding was validated, as well as the number of references (words, phrases, or paragraphs) that were coded for building evidence. Once the external sources dataset comprised updated and evidence-based descriptions of EID and IS, their references coded at emerging categories and subcategories improved the internal validity, generalizability, and theoretical level of the framework that emerged from the BIE case study.

Table 9 – The summary of external source material coding

| Type | Name | Nodes | References | Created On | Created By | Modified On |
|---|---|---|---|---|---|---|
| PDF | 2007 – Pellegatti | 29 | 946 | 28/07/2012 5:22 PM | LQ | 30/07/2012 8:50 AM |
| PDF | 2010 – Yuan *et al*. | 11 | 122 | 01/08/2012 2:56 PM | LQ | 01/08/2012 2:56 PM |
| PDF | 2011 – Atitude | 20 | 340 | 28/07/2012 5:22 PM | LQ | 28/07/2012 5:27 PM |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | 14 | 134 | 28/07/2012 5:22 PM | LQ | 28/07/2012 5:27 PM |
| PDF | 2011 – Sakr *et al*. | 22 | 340 | 28/07/2012 5:22 PM | LQ | 28/07/2012 5:27 PM |
| PDF | 2012 – Behera *et al*. | 24 | 417 | 28/07/2012 5:22 PM | LQ | 28/07/2012 5:27 PM |
| PDF | 2012 – Chertow and Ehrenfeld | 15 | 356 | 28/07/2012 5:22 PM | LQ | 28/07/2012 5:27 PM |
| PDF | 2012 – Paquin and Howard-Grenville | 9 | 165 | 31/07/2012 8:59 AM | LQ | 31/07/2012 8:59 AM |

Source: Adapted by the author from NVivo 10.

#### *4.1.2.1 The summary of external source materials*

Pellegatti (2007) describes a business plan for an eco-industrial development initiative in the Amazon geo-economic region. Specifically, this is a regional project of industrial symbiosis involving three counties in the Brazilian state of Pará: Almerim, Laranjal do Jarí and Vitória do Jarí. The planned industrial ecosystem illustrated by Pellegatti (2007) is centered on the concept of sustainable production of cellulose fibers using by-products and wastes from the pulp and paper manufacturer Jari Celulose S.A. The fashion industry is the planned industrial ecosystem's commercial target.

Yuan *et al*. (2010) give details about the management systems adopted by two Chinese government agencies to promote and regulate the development of eco-industrial parks (EIP). Initially, Yuan *et al*. (2010) set out how the State Environmental Protection Administration (SEPA) manages the National Pilot EIP Program (NPEIPP). Then, Yuan *et al*. (2010) explain how the National Development and Reform Commission (NDRC) runs the National Pilot Circular Economy Zone Program (NPCEZP).

Atitude (2011) was commissioned by Natura to provide an overview of the most prominent EID initiatives in North America and Europe. In Atitude's (2011) study, the following cases and EID specialists were identified:

a) in Canada, Taiganova Eco-Industrial Park and Ecoindustrial Solutions; Burnside Industrial Park; Dalhousie University and Raymond Côté;
b) in the United States, EID initiatives of the Government of Minnesota and Tim Nolan; Yale University and Marian Chertow; Fort Devens and Peter Lowitt and Neil Angus;
c) in Portugal, 3Drivers and Inês Costa;
d) in England, NISP and Peter Layborne;

e) in Scotland, Binn Ecopark and John Ferguson;

f) in Denmark, Kalundborg and Jorgen Christensen;

g) in Germany, Knapsac and its coordinating organization Infraserv Höchst.

Boons, Spekkink, and Mouzakitis (2011) present a theoretical framework for industrial symbiosis development following a thorough literature review of 102 scientific articles retrieved from ISI Web of Science. Sakr *et al*. (2011) identify the critical success and limiting factors for eco-industrial development based on a comprehensive literature review of 78 eco-industrial parks around the world.

Behera *et al*. (2012) illustrate the management system coordinated by the Korean Industrial Complex Corporation (KICOX) for the creation of eco-industrial parks in Ulsan, Korea. Chertow and Ehrenfeld (2012) present a theory of industrial symbiosis development based on an examination of ten industrial ecosystems from around the globe, including Kalundborg (Denmark), Guayama (Puerto Rico), Shenzhen Huaqiu Holdings Ltd. (China), and Rotterdam Harbor (Netherlands) (the Netherlands). Paquin and Howard-Grenville (2012) demonstrate empirically how an IS initiative developed and evolved over a period of eight years in the UK industrial sector under the direction of the National Industrial Symbiosis Programme (NISP).

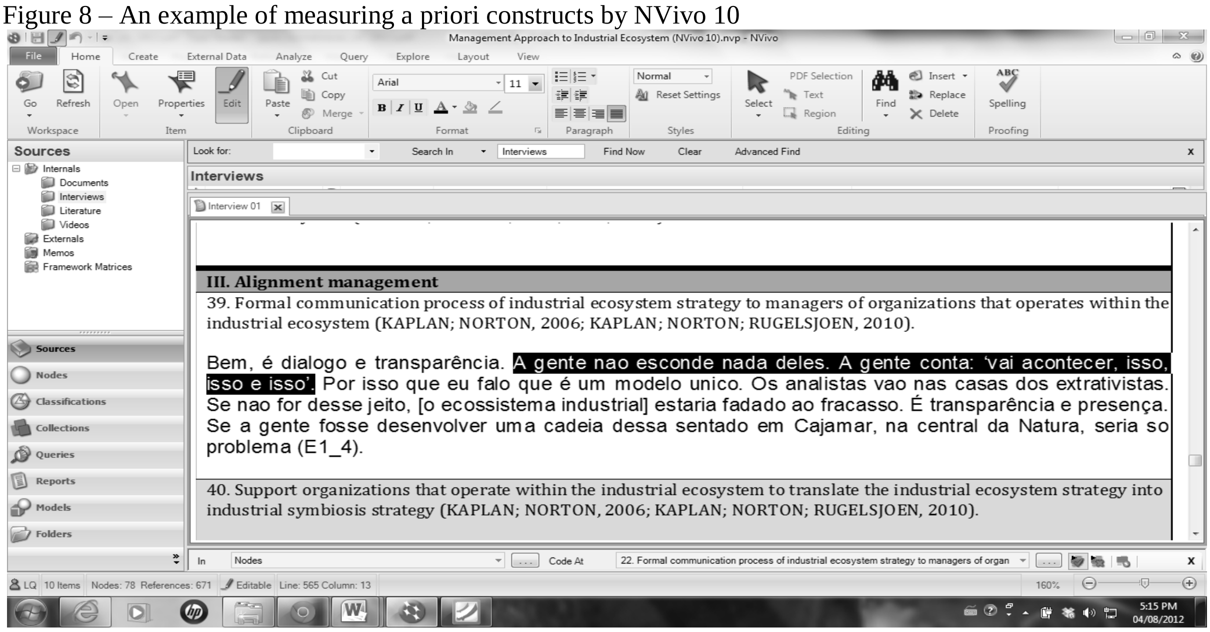
### 4.2 Measuring a-priori constructs

Measuring a priori constructs was the first step of coding to gather evidence of an EID management process within the Benevides Industrial Ecosystem dataset. It was a two-step process that involved refining the definitions of a priori categories and subcategories from Table 2 and constructing evidence by coded references (i.e., words, phrases, or paragraphs) in within-case analysis on BIE data. Through constant comparison analysis (STRAUSS; CORBIN, 2008) between a priori constructs and BIE data, both processes occurred. The researcher created an emerging category or subcategory by finding evidence in the within-case analysis regarding a corresponding a priori construct.

The researcher utilized “constant comparison analysis” while reading the entire dataset from the within-case analysis of Benevides Industrial Ecosystem. Constant comparison analysis consisted of selecting references from the source materials and identifying similarities between them and the a priori constructs. Therefore, deductive reasoning was utilized. The researcher coded the selected reference at a single “node” that corresponds to a particular a priori category or subcategory listed in Table 4.

Figure 8 illustrates the researcher's use of NVivo when measuring a priori constructs in order to demonstrate the application of constant comparison analysis (LEECH; ONWUEGBUZIE, 2007; 2008; 2011). As seen in Figure 8, after reading the transcript of Interview 01, the researcher selected the cited reference, "A gente nao esconde nada deles. A gente conta: vai acontecer isso, isso e isso." He then posed the following question to the chosen reference: "The action of disclosing the BIE strategy plan is associated with which a priori construct?" The researcher realized that this action constitutes a formal communication procedure. Therefore, the researcher coded the selected reference at a single "node," which represents the a-priori subcategory "formal communication process of industrial ecosystem strategy to managers of organizations that operate within the industrial ecosystem," which is directly related to the a-priori category "alignment management."

Figure 8 – An example of measuring a priori constructs by NVivo 10




Source: Adapted by the author from NVivo 10.

This theoretical comparison analysis was performed numerous times at the micro level throughout the source materials of the Benevides Industrial Ecosystem's within-case analysis. The researcher employed axial coding to validate all a priori constructs in Table 2. After all source materials have been coded, the emerging nodes become well-defined, evidence-based categories and subcategories, as shown in Table 10. Clearly, constructs have emerged as a result of axial coding. On the other hand, those unsupported a priori constructs were discarded.

Table 10 – The emerging categories and subcategories from axial coding

| A MANAGEMENT APPROACH TO THE INDUSTRIAL ECOSYSTEM |
|---|
| **1. THE OFFICE OF ECO-INDUSTRIAL DEVELOPMENT (OEID)** |
| **2. INDUSTRIAL ECOSYSTEM STRATEGY DEVELOPMENT** |
| **2.1 Clarification of mission, values and vision** |
| **2.2 Strategic Analysis** |
| ***2.2.1 Definition of the extent of industrial ecosystem*** |
| ***2.2.2 Identification of the points of intersection between industrial ecosystem, society and natural ecosystem*** |
| ***2.2.3 Choosing of social issues to address through industrial ecosystem*** |
| ***2.2.4 Risk analysis*** |
| ***2.2.5 Mapping to identify potential symbiosis*** |
| **2.3 Formulation of Strategy** |
| ***2.3.1 Definition of the ecosystem value proposition*** |
| ***2.3.2 Definition of CSR*** |
| *2.3.2.1 Responsive CSR* |
| *2.3.2.2 Strategic CSR* |
| ***2.3.3 Definition of symbioses*** |
| *2.3.3.1 Definition of firms* |
| *2.3.3.2 Definition of the champion* |
| *2.3.3.3 Objectives, metrics, targets, initiatives and budget (OMTIB) for creating learning and growth* |
| *2.3.3.4 Objectives, metrics, targets, initiatives and budget (OMTIB) for integrating practices* |
| *2.3.3.5 Objectives, metrics, targets, initiatives and budget (OMTIB) for creating a social dimension to the value proposition* |
| *2.3.3.6 Definition of benefits* |
| ***2.3.4 Definition of enablers*** |
| *2.3.4.1 Definition of the human capital capabilities required* |
| *2.3.4.2 Definition of the technology enablers of the strategy* |
| *2.3.4.3 Definition of the financial enablers of the strategy* |
| *2.3.4.4 Definition of partners* |
| *2.3.4.5 Definition of policy and regulatory framework* |
| **3. ALIGNMENT MANAGEMENT** |
| **3.1 Formal communication process of industrial ecosystem strategy to managers of organizations that operates within the industrial ecosystem** |
| **3.2 Support organizations that operate within the industrial ecosystem to translate the industrial ecosystem strategy into industrial symbiosis strategy** |
| **4. INDUSTRIAL SYMBIOSIS MANAGEMENT** |
| **4.1 Development of industrial symbiosis strategy** |
| **4.2 Alignment of employees with industrial symbiosis strategy through communication and incentives** |
| **4.3 Planning of industrial symbioses** |
| **4.4 Accountability of industrial symbiosies** |
| **4.5 Monitoring of execution of industrial symbiosis** |
| **5. ACCOUNTABILITY MANAGEMENT** |
| **5.1 Monitor and learn about problems, barriers, and challenges through metrics** |
| **6. SYSTEM ADAPTATION MANAGEMENT** |
| **6.1 Use of internal operational data and new external environmental and competitive data to test and adapt the industrial ecosystem strategy, launching another loop around the integrated strategy planning and operational execution system** |

Source: Adapted by the author from NVivo 10.

As shown in Table 11, the emerging constructs were grouped under the theme "management approach to the industrial ecosystem." It combines the number of sources used for measuring a priori constructs with the number of references coded for constructing evidence.

Table 11 – The core category "management approach to industrial ecosystem" and its sucategories

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| Management approach to industrial ecosystem | 23 | 2405 | 02/07/2012 11:52 AM | LQ |
| I. The office of eco-industrial development (OEID) | 13 | 173 | 31/07/2012 4:13 PM | LQ |
| II. Industrial ecosystem strategy development | 22 | 870 | 02/07/2012 11:53 AM | LQ |
| III. Alignment management | 20 | 391 | 02/07/2012 11:54 AM | LQ |
| IV. Industrial symbiosis management | 20 | 493 | 02/07/2012 11:54 AM | LQ |
| V. Accountability management | 16 | 119 | 02/07/2012 11:54 AM | LQ |
| VI. System adaptation management | 16 | 62 | 02/07/2012 11:55 AM | LQ |

Source: Adapted by the author from NVivo 10.

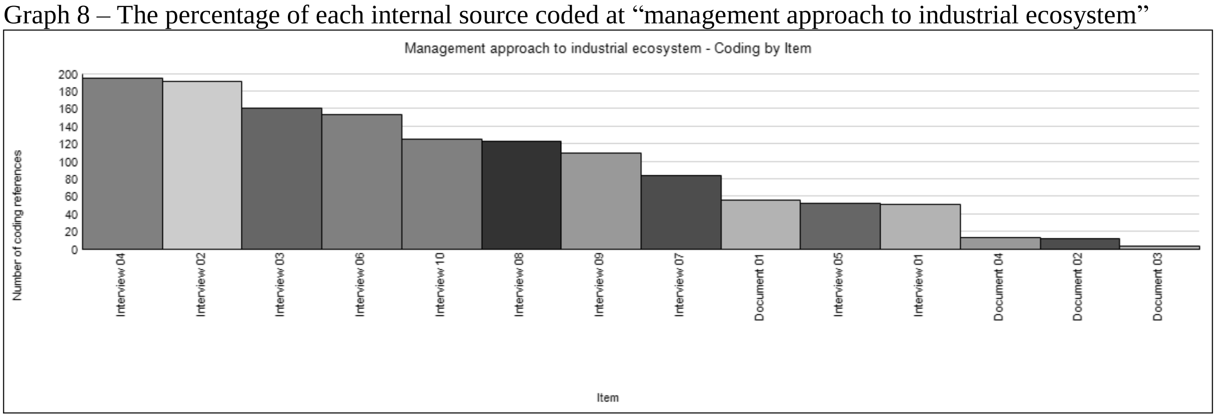
Table 12 displays the names of the internal sources that were coded under the theme “management approach to the industrial ecosystem,” as well as the number of references coded and the proportion of the source represented by the coding. In Graph 8, the percentage of each source that has been coded for this theme is displayed. Graph 9 displays a tree map of the emerging categories and subcategories compared by the number of coded references in order to illustrate the most frequently discussed topics by interviewees.

Table 12 – The internal sources coded at “management approach to industrial ecosystem”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 56 | 37.73% |
| Document | Document 02 | Internals\\Documents | 12 | 14.23% |
| Document | Document 03 | Internals\\Documents | 4 | 3.32% |
| Document | Document 04 | Internals\\Documents | 14 | 14.16% |
| Transcript | Interview 01 | Internals\\Interviews | 51 | 20.09% |
| Transcript | Interview 02 | Internals\\Interviews | 191 | 54.40% |
| Transcript | Interview 03 | Internals\\Interviews | 161 | 59.11% |
| Transcript | Interview 04 | Internals\\Interviews | 195 | 67.11% |
| Transcript | Interview 05 | Internals\\Interviews | 52 | 42.63% |
| Transcript | Interview 06 | Internals\\Interviews | 154 | 62.59% |
| Transcript | Interview 07 | Internals\\Interviews | 84 | 53.57% |
| Transcript | Interview 08 | Internals\\Interviews | 123 | 49.73% |
| Transcript | Interview 09 | Internals\\Interviews | 110 | 54.56% |
| Transcript | Interview 10 | Internals\\Interviews | 125 | 58.87% |

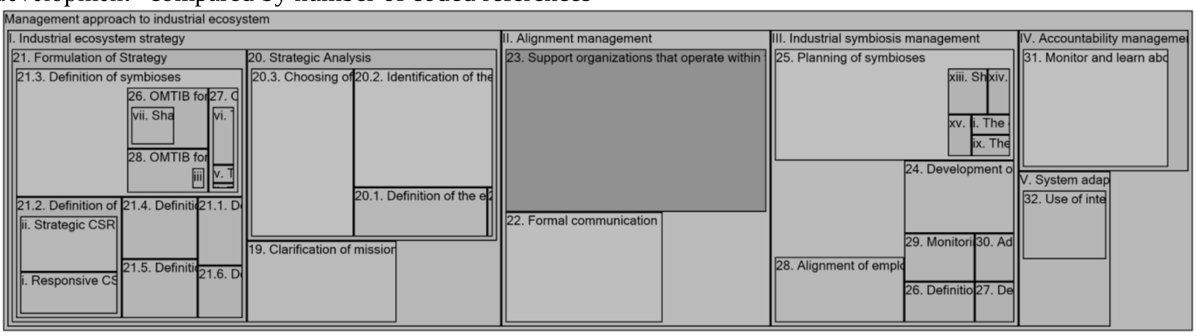
Source: Adapted by the author from NVivo 10.

Graph 8 – The percentage of each internal source coded at “management approach to industrial ecosystem”




Source: Adapted by the author from NVivo 10.

Graph 9 – The categories and subcategories of the theme “management approach to industrial ecosystem development” compared by number of coded references

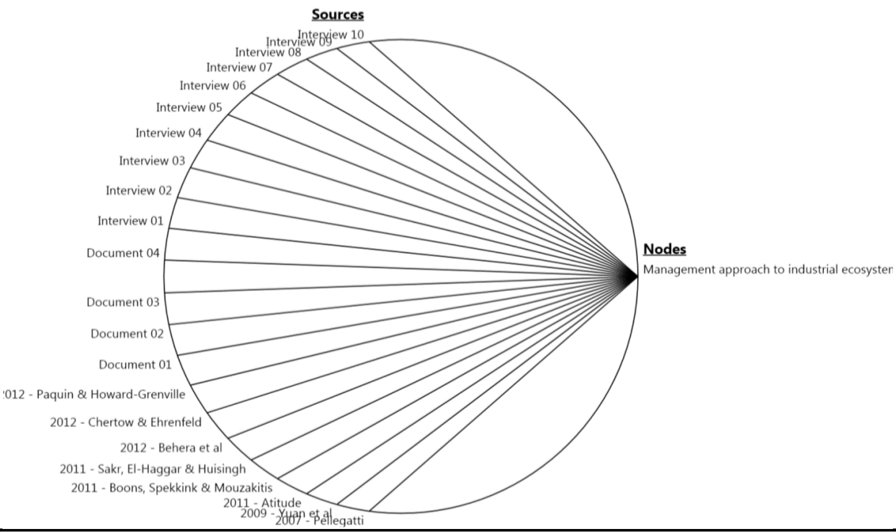



Source: Adapted by the author from NVivo 10.

Implementing Step 3 of the analytical scheme depicted in Table 4, the researcher coded the entire literature dataset in order to gather evidence similar to the categories and subcategories that emerged from the within-case analysis of the Benevides Industrial Ecosystem (TABLE 10). The researcher reapplied constant comparison analysis (STRAUSS; CORBIN, 2008) in accordance with the previously described method.

At Step 4, the nodes resulting from the literature dataset were utilized in a “group query” through NVivo 10 to validate the emerging categories and subcategories listed in Table 10. To this end, the group query identified constructs in internal source material that were associated in a particular way with constructs within external source material. After executing the group query, the results were displayed automatically in Graph 10.

Graph 10 – Group query result for “management approach to industrial ecosystem”




Source: Adapted by the author from NVivo 10.

Graph 10 demonstrates that the industrial ecosystem management approach utilized by OERM in the Benevides Industrial Ecosystem is comparable to the management systems for eco-industrial development depicted in the cases presented by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010). The similarity among all these management systems strengthens the internal validity, generalizability, and theoretical level of the proposed framework for eco-industrial development management.

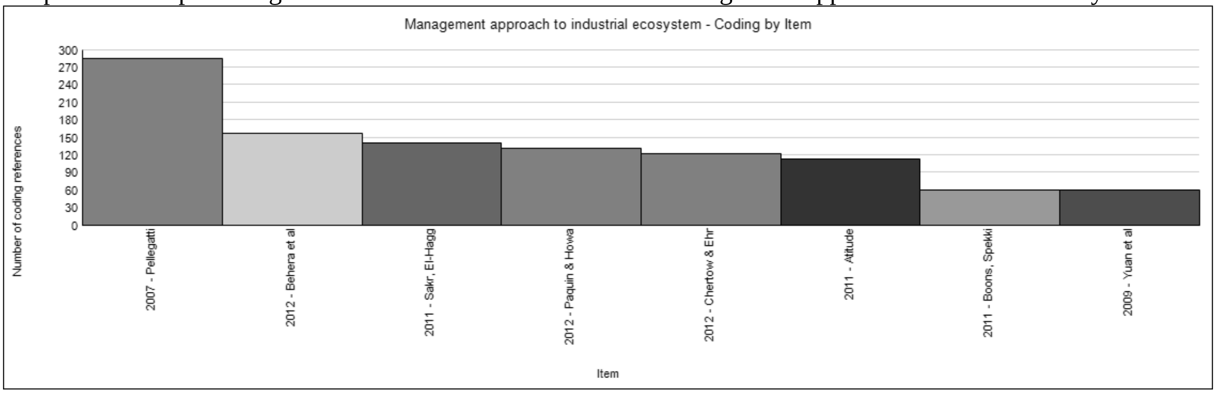
On the following page, Table 13 provides the names of the external sources coded for the theme “management approach to the industrial ecosystem,” as well as the number of references coded and the proportion of the source represented by the coding. In Graph 11, a chart depicts the percentage of each source that has been coded for this theme.

Table 13 – The external source materials coded at “management approach to industrial ecosystem”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2007 – Pellegatti | Internals\\Literature | 286 | 36.90% |
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 57 | 26.17% |
| PDF | 2011 – Atitude | Internals\\Literature | 114 | 31.01% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 61 | 11.39% |
| PDF | 2011 – Sakr *et al*. | Internals\\Literature | 141 | 18.56% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 156 | 24.55% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 123 | 19.12% |
| PDF | 2012 – Paquin and Howard-Grenville | Internals\\Literature | 132 | 23.18% |

Source: Adapted by the author from NVivo 10.

Graph 11 – The percentage of each external source coded at “management approach to industrial ecosystem”




Source: Adapted by the author from NVivo 10.

## 4.3 Coding results: categories and subcategories

This section defines the categories and subcategories listed in Table 10 that make up the proposed theoretical framework. In addition, it describes how these constructs were measured using constant comparison analysis with open coding, axial coding, and selective coding, as well as a review of the literature and validation based on a comparison to previous research. Briefly, Section 4.3 discusses the emergence of a number of eco-industrial development management concepts and processes.

### *4.3.1 The office of eco-industrial development*

The evidence indicates that the category “Office of Eco-Industrial Development” refers to an organization responsible for coordinating the management of eco-industrial development. Using open coding and axial coding, the researcher extracted the category “Office of Eco-Industrial Development” from the collected data. Table 14 displays the result of the coding for this construct in the Benevides Industrial Ecosystem dataset. It combines the number of sources used for measuring the construct and the number of references coded to generate evidence.

Table 14 – The category “the office of eco-industrial development”

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| I. The office of eco-industrial development (OEID) | 13 | 173 | 31/07/2012 4:13 PM | LQ |

Source: Adapted by the author from NVivo 10.

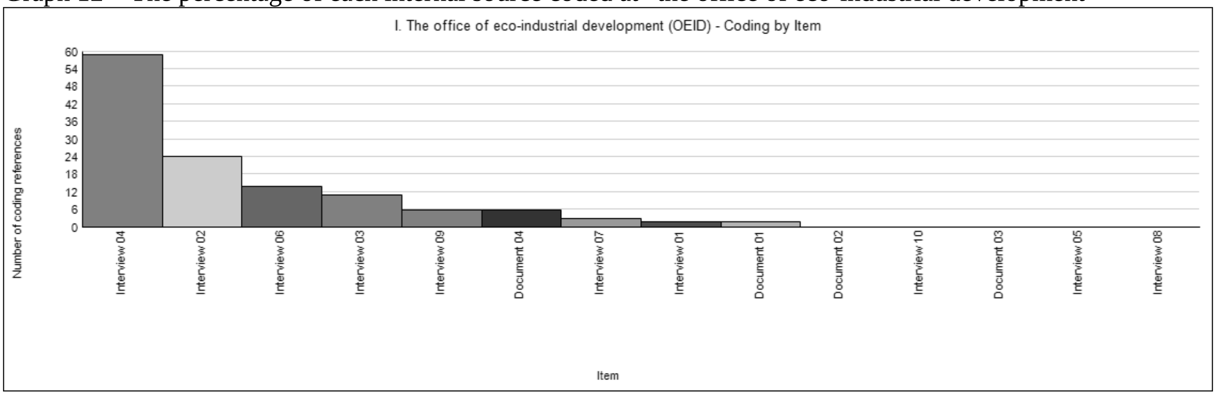
Table 15 displays the names of the internal sources that were coded in the category “Office of Eco-Industrial Development,” as well as the number of references coded and the percentage of the source that the coding represents. In Graph 12, a chart depicts the proportion of each source that has been coded. Note that Interview 04 with an OERM eco-relationship analyst was the internal source that contributed the most to defining the construct.

Table 15 – The internal source materials coded at “the office of eco-industrial development”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 2 | 1.80% |
| Document | Document 04 | Internals\\Documents | 6 | 9.02% |
| Transcript | Interview 01 | Internals\\Interviews | 2 | 1.70% |
| Transcript | Interview 02 | Internals\\Interviews | 24 | 11.48% |
| Transcript | Interview 03 | Internals\\Interviews | 11 | 6.75% |
| Transcript | Interview 04 | Internals\\Interviews | 59 | 27.30% |
| Transcript | Interview 06 | Internals\\Interviews | 14 | 7.30% |
| Transcript | Interview 07 | Internals\\Interviews | 3 | 2.22% |
| Transcript | Interview 09 | Internals\\Interviews | 6 | 3.55% |

Source: Adapted by the author from NVivo 10.

Graph 12 – The percentage of each internal source coded at “the office of eco-industrial development”




Source: Adapted by the author from NVivo 10.

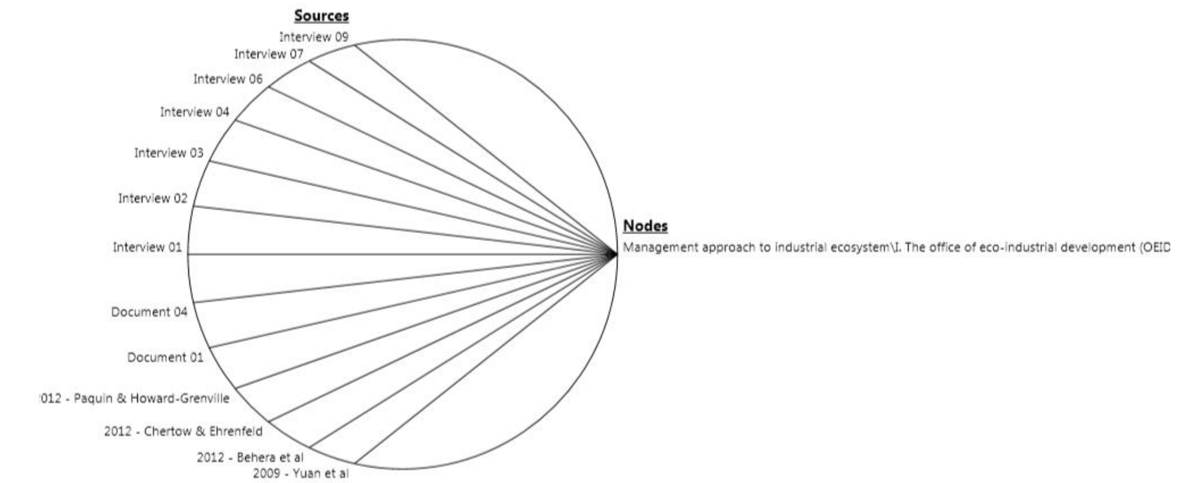
The following are examples of internal references used to form the category “Office of Eco-Industrial Development”:

> [A area de eco-relaçoes tem como premissa] desenvolver os processos entre as organizações (DOCUMENT 04 ¶130).
>
> [A area de eco-relaçoes] é composta por pessoas com habilidades especiais. Todos eles têm uma funçao de relacionamento. Eles se preocupam com a parte de capacitaçao e de

> como esta sendo produzido. Ela estabelece as relaçoes. Ela sabe como lidar com eles. Caso nao haja isso, nao ha produtividade (INTERVIEW 01 ¶177).
>
> [Quando] a Natura tem uma demanda por produtos da biodiversidade, o **Xxxxx**[46] e o **Xxxxx** vao conhecer essas organizaçoes [cooperativas, associaçoes], entender como funciona o modelo de negocio, de trabalho, dessas organizaçoes. Depois de um ano conhecendo e indo la, eles estabelecem uma meta minima de produçao para eles, por exemplo, x toneladas. Depois de um ano [de fornecimento], eles passam para mim e **Xxxxx** [analistas de eco-relaçoes] a situaçao [da cooperativa] e nos pedem pra tocar [administrar o processo]. Eles passam as informaçoes de como é o trabalho [nas cooperativas] e quem sao as pessoas-chave. (INTERVIEW 04 ¶62).

After defining the category "Office of Eco-Industrial Development" based on BIE data, the researcher performed Step 3 of the analytical scheme depicted in Table 4. The entire set of external sources was coded to gather evidence pertaining to the "Office of Eco-Industrial Development." At Step 4, the nodes resulting from the literature dataset were incorporated into a group query in NVivo 10 to validate this construct. As a result, the group query identified internal sources associated in a particular way with external ones. After executing the query, the results were displayed automatically in Graph 13.

Graph 13 – Group query result for the category "the office of eco-industrial development"




Source: Adapted by the author from NVivo 10.

Graph 13 demonstrates that the Benevides Industrial Ecosystem and the eco-industrial development initiatives delineated by Behera *et al*. (2012), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), and Yuan *et al*. (2010) are managed by a coordinating organization employing comparable management procedures.

Table 16 presents the names of the external sources that were coded in the category "Office of Eco-Industrial Development" as well as the number of references that validated this

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[46]***Xxxxx*** alludes to the names of the OERM members that were hidden to protect their personal identification.

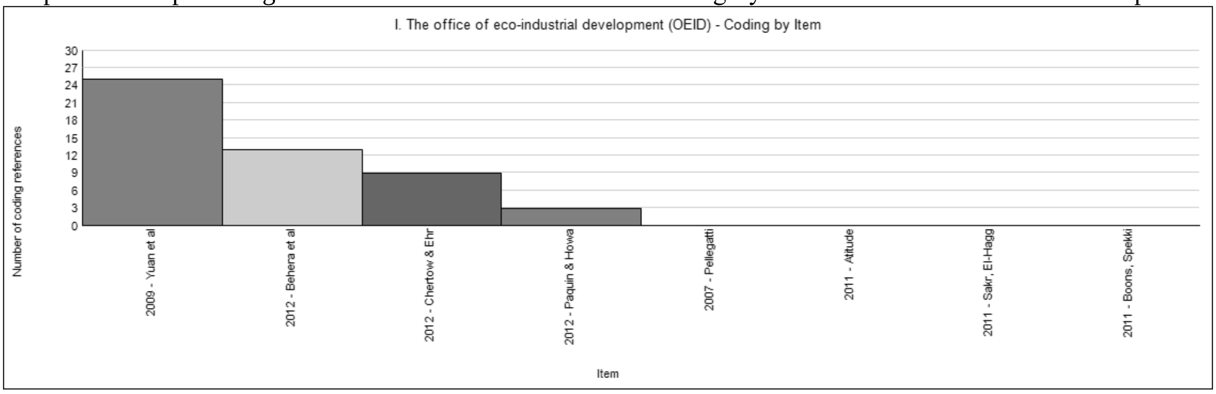
construct and the percentage of the source represented by coding. In Graph 14, a bar graph depicts the proportion of each source coded at this construct.

Table 16 – The summary of the external source materials coded at the category “the office of eco-industrial development”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 21 | 9.76% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 13 | 2.75% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 9 | 1.61% |
| PDF | 2012 – Paquin and Howard-Grenville | Internals\\Literature | 3 | 0.35% |

Source: Adapted by the author from NVivo 10.

Graph 14 – The percentage of each external source coded at the category “the office of eco-industrial development”




Source: Adapted by the author from NVivo 10.

### *4.3.2 Industrial ecosystem strategy development*

Based on the avaible evidence, the category “industrial ecosystem strategy development” and its subcategories refer to the formulation of at least one industrial symbiosis aimed at cost reduction, revenue enhancement, or business expansion while also creating positive externalities. To be successful, this type of strategy requires a key organization and enablers, such as partners, a policy and regulatory framework, human capital, technology, and financial support.

The researcher derived the category “industrial ecosystem strategy development” from the data using open coding and axial coding. On the next page, Table 17 displays the results of the coding for the category “industrial ecosystem strategy development” and its subcategories in the Benevides Industrial Ecosystem dataset. It includes the number of sources utilized to measure this category and its subcategories, as well as the number of references that have been coded.

Table 17 – The category “industrial ecosystem strategy development” and subcategories

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| II. Industrial ecosystem strategy development | 22 | 870 | 02/07/2012 11:53 AM | LQ |
| 19. Clarification of mission, values and vision | 15 | 51 | 02/07/2012 11:56 AM | LQ |
| 20. Strategic Analysis | 18 | 276 | 10/07/2012 9:46 AM | LQ |
| 20.1. Definition of the extent of industrial ecosystem | 5 | 43 | 07/07/2012 10:43 AM | LQ |
| 20.2. Identification of the points of intersection betwe | 11 | 84 | 02/07/2012 11:57 AM | LQ |
| 20.3. Choosing of social issues to address through in | 13 | 87 | 02/07/2012 11:57 AM | LQ |
| 20.4. Risk analysis | 4 | 5 | 12/07/2012 10:07 PM | LQ |
| 20.5. Mapping to identify potential symbiosis | 2 | 33 | 30/07/2012 5:42 PM | LQ |
| 21. Formulation of Strategy | 21 | 498 | 10/07/2012 9:51 AM | LQ |
| 21.1. Definition of the ecosystem value proposition | 5 | 32 | 02/07/2012 12:04 PM | LQ |
| 21.2. Definition of CSR | 9 | 63 | 10/07/2012 11:51 AM | LQ |
| i. Responsive CSR | 4 | 23 | 02/07/2012 11:58 AM | LQ |
| ii. Strategic CSR | 5 | 31 | 02/07/2012 11:58 AM | LQ |
| 21.3. Definition of symbioses | 19 | 258 | 02/07/2012 12:05 PM | LQ |
| i. Definition of firms | 2 | 9 | 01/08/2012 9:16 AM | LQ |
| ii. Definition of the champion | 4 | 18 | 30/07/2012 5:44 PM | LQ |
| iii. OMTIB for creating learning and growth | 5 | 28 | 02/07/2012 12:08 PM | LQ |
| iv. OMTIB for integrating practices | 8 | 47 | 02/07/2012 12:09 PM | LQ |
| v. OMTIB for creating a social dimension to the v | 4 | 19 | 02/07/2012 12:10 PM | LQ |
| vi. Definition of benefits | 3 | 24 | 31/07/2012 7:13 PM | LQ |
| 21.4. Definition of enablers | 15 | 111 | 31/07/2012 2:13 PM | LQ |
| i. Definition of the human capital capabilities requ | 9 | 32 | 02/07/2012 12:10 PM | LQ |
| ii. Definition of the technology enablers of the str | 9 | 43 | 02/07/2012 12:11 PM | LQ |
| iii. Definition of the financial enablers of the strat | 4 | 19 | 08/07/2012 4:05 PM | LQ |
| iv. Definition of partners | 4 | 12 | 30/07/2012 2:39 PM | LQ |
| v. Definition of policy and regulatory framework | 2 | 2 | 31/07/2012 2:14 PM | LQ |

Source: Adapted by the author from NVivo 10.

Table 18 displays the names of the internal sources that were coded for the category “industrial ecosystem strategy development” and its subcategories, as well as the number of references that were coded and the percentage of the source represented by the coding.

Table 18 – The internal source materials coded at the category “industrial ecosystem strategy development”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 31 | 20.97% |
| Document | Document 02 | Internals\\Documents | 4 | 4.78% |
| Document | Document 03 | Internals\\Documents | 4 | 3.32% |
| Document | Document 04 | Internals\\Documents | 1 | 1.37% |
| Transcript | Interview 01 | Internals\\Interviews | 31 | 12.72% |
| Transcript | Interview 02 | Internals\\Interviews | 63 | 19.99% |
| Transcript | Interview 03 | Internals\\Interviews | 66 | 27.89% |
| Transcript | Interview 04 | Internals\\Interviews | 74 | 26.15% |
| Transcript | Interview 05 | Internals\\Interviews | 36 | 28.47% |
| Transcript | Interview 06 | Internals\\Interviews | 25 | 12.44% |
| Transcript | Interview 07 | Internals\\Interviews | 31 | 15.53% |
| Transcript | Interview 08 | Internals\\Interviews | 48 | 17.97% |
| Transcript | Interview 09 | Internals\\Interviews | 17 | 10.32% |
| Transcript | Interview 10 | Internals\\Interviews | 88 | 37.50% |

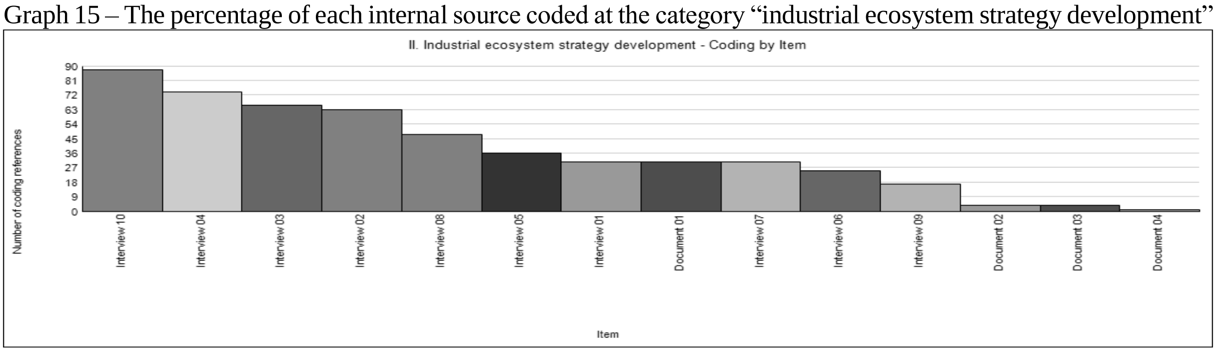
Source: Adapted by the author from NVivo 10.

The following sentences are examples of references from the internal sources used for shaping the construct “industrial ecosystem strategy development” and its subcategories:

> Ao mesmo tempo, reconhecemos que os desafios da sustentabilidade só podem serenfrentados de maneira conjunta, pois os conhecimentos e esforços necessários extrapolam as capacidades individuais e de organizações isoladas (DOCUMENT 01 ¶22). Não apenas o uso de nossos produtos deve promover prazer e bem-estar. Sua criação, produção e comercialização devem ser projetadas para trazer benefícios a todos os envolvidos (DOCUMENT 01 ¶201).
>
> É uma dimensao bastante complexa. Em um processo desse, articular essa simbiose para que todo mundo consiga ter uma compreensao dentro de um sistema desse, isso nao é facil. Isso depende muito da capacidade dos profissionais em [perceber a harmonia] nesse conjunto de relaçoes. Eu acho que isso ai é o desafio.Por exemplo, em um mecanismo como esse da Natura, tem que ter um pé la na comunidade, mas junto [disso], ha uma serie de outras empresas que estao articuladas à Natura que precisam entender o aspecto cultural e a questao ambiental que precisam ser levados em consideraçao.Construir isso aqui é uma tarefa muito complicada nas empresas [atreladas à Natura].Vai depender muito da compreensao de quem compoe esse sistema da empresa para ter justamente essa dimensao para dialogar com esses interessados la [na base].Nao adianta, pois alguma coisa quebra e nao funciona se nao tiver essa [harmonia] nessas diversas dimensoes.Precisa sim afinar e isso depende muito de quem desenvolve esse mecanismo dentro desse sistema.Isso nao deve ser uma tarefa muito facil. É de uma complexidade muito grande, mas nao no sentido de que nao é possivel resolver. Para isso, uma equipe multidisciplinar é imprescindivel para entender esses diversos aspectos (INTERVIEW 09 ¶56).
>
> [A estratégia] é valorizar a autonomia, a autogestao.Para o estabelecimento da simbiose industrial, existe a questao dos conflitos de interesses.Os extrativistas querem uma coisa, a industria quer outra.Para se obter essa simbiose, a gente tem que ter muito cuidado com essas divergências.Ha divergências culturais, porque a empresa tem um tempo e o produtor tem outro, pois ele pensa diferente da empresa, tem uma logica diferente, tem problemas de infraestrutura e de transporte.Teria que levar em conta isso para se conseguir realmente chegar [a uma simbiose industrial] (INTERVIEW 10 ¶35).

There is a chart depicting the percentage of each source that was coded in Graph 15. Notably, Interview 10 with a FASE consultant was the internal source that had the greatest influence on the formation of the constructs.

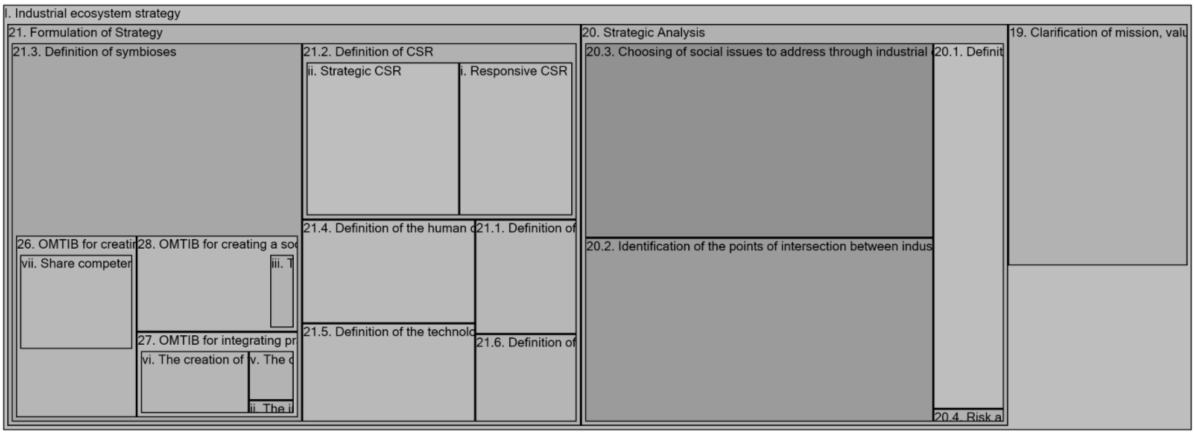
Graph 15 – The percentage of each internal source coded at the category “industrial ecosystem strategy development”




Source: Adapted by the author from NVivo 10.

Graph 16 depicts a tree map with emerging subcategories compared by the number of coded references to demonstrate the most frequently discussed topics among the interviewees. The square size indicates the number of coded references that validate a subcategory. The larger the square, the more corroborating evidences there are for a construct. As illustrated in Graph 16, a substantial body of evidence seems to validate the subcategories “clarification of mission, values, and vision,” “selection of social issues to address,” and “definition of symbioses.”

Graph 16 – The subcategories of the category “industrial ecosystem strategy development” compared by number of coded references

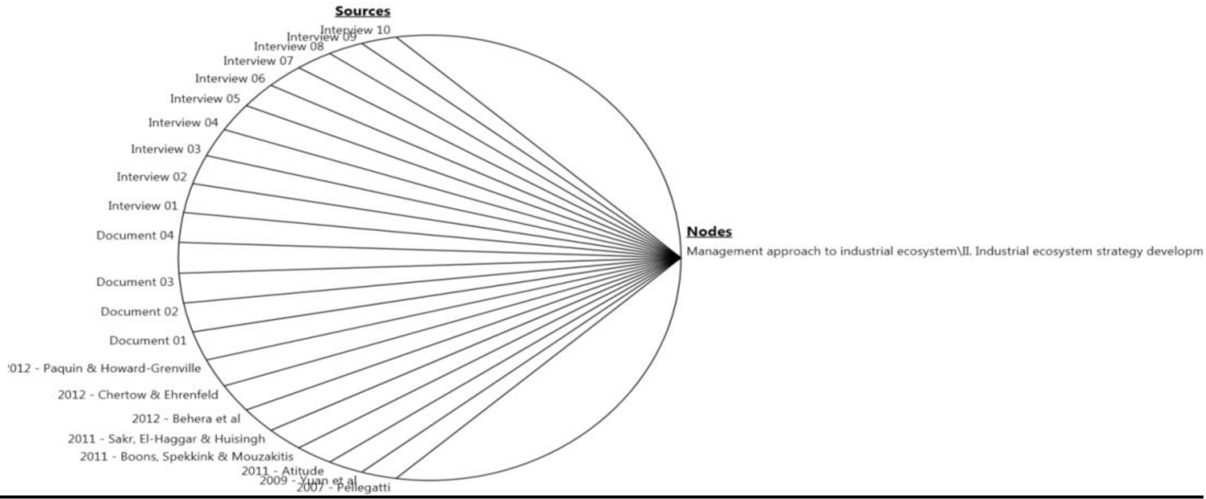



Source: Adapted by the author from NVivo 10.

The researcher completed Step 3 of the analytical scheme depicted in Table 4 after defining the category “industrial ecosystem strategy development” and its subcategories based on BIE data. The entire set of external sources has been coded to look for evidence of “industrial ecosystem strategy development” and its subcategories. Step 4 consisted of incorporating the nodes resulting from the literature dataset into a group query in NVivo 10 to validate the constructs. As a result, the group query identified internal sources that were uniquely associated with external sources. After the query was executed, the results were displayed automatically in Graph 17.

Graph 17 demonstrates that the industrial ecosystem strategy development process utilized by OERM in the Benevides Industrial Ecosystem is comparable to the articulation of industrial symbiosis described by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010). In every instance of industrial symbiosis formulation, the relationship between business factors and positive externalities was the most consistent element.

Graph 17 – Group query result for the category “industrial ecosystem strategy development”




Source: Adapted by the author from NVivo 10.

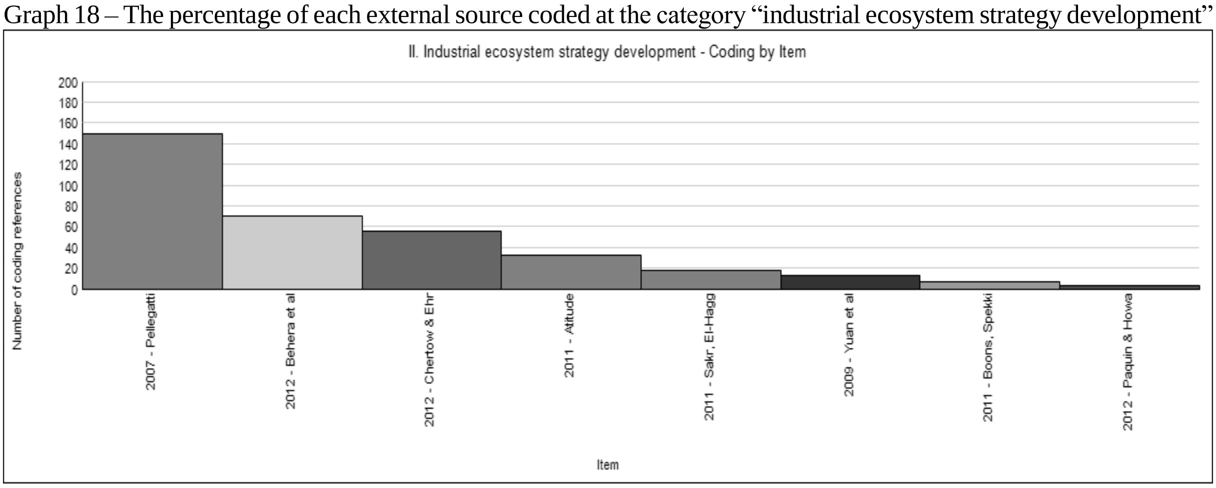
Table 19 lists the external sources that were coded for the category “industrial ecosystem strategy development” and its subcategories, as well as the number of references that validated them and the proportion of the source that coding represents. There is a chart depicting the percentage of each source coded in Graph 18.

Table 19 – The summary of the external source materials coded at the category “industrial ecosystem strategy development”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2007 – Pellegatti | Internals\\Literature | 150 | 21.03% |
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 13 | 6.89% |
| PDF | 2011 – Atitude | Internals\\Literature | 33 | 6.12% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 7 | 1.23% |
| PDF | 2011 – Sakr *et al*. | Internals\\Literature | 18 | 2.47% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 70 | 10.25% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 56 | 6.97% |
| PDF | 2012 – Paquin and Howard-Grenville | Internals\\Literature | 4 | 0.90% |

Source: Adapted by the author from NVivo 10.

Graph 18 – The percentage of each external source coded at the category “industrial ecosystem strategy development”




Source: Adapted by the author from NVivo 10.

### *4.3.3 Alignment management*

According to the evidence, “alignment management” refers to the incorporation of an industrial ecosystem strategy into the strategies and operations of businesses, non-governmental organizations, government agencies, labor unions, universities, and research centers participating in an eco-industrial development initiative. After attracting new entrants into the industrial ecosystem with the promise of cost reduction, revenue enhancement, business expansion, or positive externalities, the office of eco-industrial development aligns these potential members through a formal communication procedure. In addition, this coordinating organization provides support services (training, consulting, and IT services) and financial aid to facilitate the implementation and operation of industrial symbioses.

With open coding and axial coding, the researcher derived the category “alignment management” based on data. Table 20 displays the results of the process of coding based on the category “alignment management” and its subcategories within the dataset pertaining to the Benevides Industrial Ecosystem. It includes the number of sources used to measure this category and its subcategories as well as the number of references to evidence that have been coded.

Table 20 – The category “alignment management” and its subcategories

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| III. Alignment management | 20 | 391 | 02/07/2012 11:54 AM | LQ |
| 22. Formal communication process of industrial ecosyste | 13 | 72 | 02/07/2012 12:16 PM | LQ |
| 23. Support organizations that operate within the industrial | 14 | 181 | 02/07/2012 12:17 PM | LQ |

Source: Adapted by the author from NVivo 10.

Table 21 displays the name of the internal sources that were coded under the category “alignment management” and its subcategories, including the number of references that were coded and the percentage of the source that the coding represents.

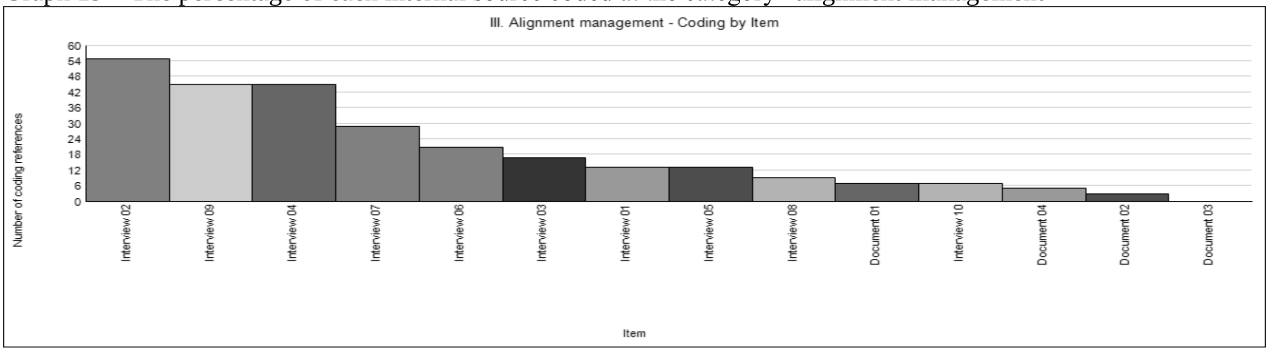
Table 21 – The summary of the internal source materials coded at “alignment management”

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 7 | 4.97% |
| Document | Document 02 | Internals\\Documents | 3 | 3.48% |
| Document | Document 04 | Internals\\Documents | 5 | 4.16% |
| Transcript | Interview 01 | Internals\\Interviews | 13 | 5.45% |
| Transcript | Interview 02 | Internals\\Interviews | 55 | 18.09% |
| Transcript | Interview 03 | Internals\\Interviews | 17 | 7.06% |
| Transcript | Interview 04 | Internals\\Interviews | 45 | 20.22% |
| Transcript | Interview 05 | Internals\\Interviews | 13 | 15.82% |
| Transcript | Interview 06 | Internals\\Interviews | 21 | 12.00% |
| Transcript | Interview 07 | Internals\\Interviews | 29 | 22.93% |
| Transcript | Interview 08 | Internals\\Interviews | 9 | 5.63% |
| Transcript | Interview 09 | Internals\\Interviews | 45 | 29.06% |
| Transcript | Interview 10 | Internals\\Interviews | 7 | 8.77% |

Source: Adapted by the author from NVivo 10.

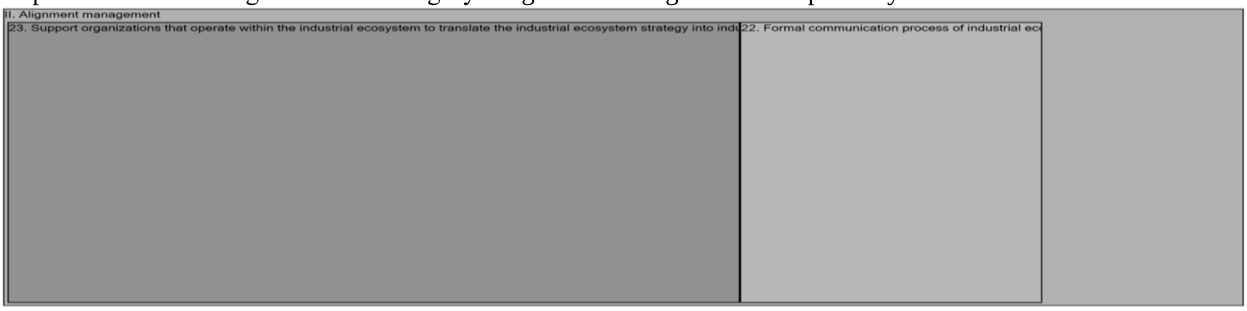
In Graph 19, a chart depicts the proportion of each source that has been coded. Note that Interview 02 with the manager of the Office of Eco-Relationships contributed the most to the formation of the category and its subcategories. Graph 20 portrays a tree map with emerging subcategories compared by the number of coded references in order to display the most frequently discussed topics by interviewees. It can be observed that the subcategory "support organizations that operate within the industrial ecosystem" was regarded as the most crucial procedure in alignment management.

Graph 19 – The percentage of each internal source coded at the category "alignment management"




Source: Adapted by the author from NVivo 10.

Graph 20 – The subcategories of the category "alignment management" compared by number of coded references




Source: Adapted by the author from NVivo 10.

The sentences that follow are examples of references from internal sources that were used to shape the category "alignment management" and its subcategories:

> E através de varias reunioes e oficinas, em 2007, explicamos: qual o interesse da Natura, o que a Natura pensava em desenvolver na regiao, quais eram os planos para o futuro, os planos de crescimento e a importância deles [extrativistas, sindicatos e ONGs] para o negocio. Até hoje, nos temos que fazer um esforço enorme. Para a gente chegar nisso, é muito importante a assessoria técnica local. Nos temos uma inserçao no campo muito grande. Nos temos uma equipe dedicada. Praticamente, 70 a 75 assessorias técnicas por ano. E uma assessoria técnica dura em média três dias (INTERVIEW 02 ¶5).

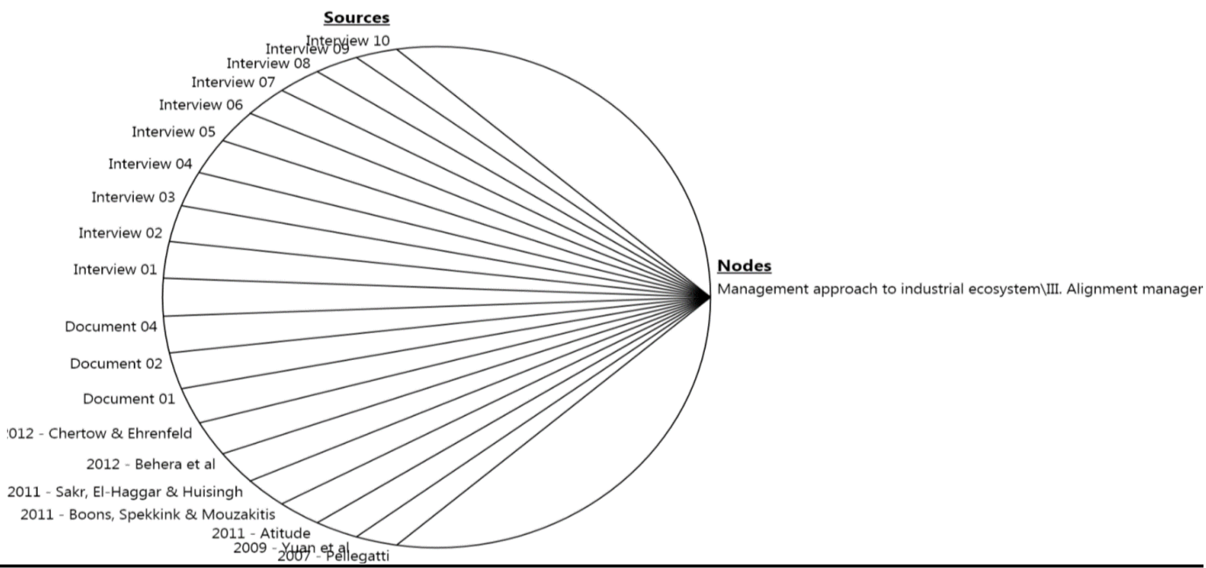
> Outro ponto importante é fortalecer as organizaçoes e as instituiçoes [que representam os agricultores], pois nos nao tratamos [diretamente] com o agricultor, mas diretamente com a cooperativa ou a associaçao. Portanto, muitas de nossas açoes têm como foco o fortalecimento do quadro social dessas cooperativas, embora isso seja

> uma grande dificuldade. Muitos socios estao cadastrados, mas nao frequentam as assembléias e as reunioes. Nos temos um trabalho junto a parceiros locais, ONGs, em que nos fornecemos para eles treinamentos em segurança e saude, contribuindo para esse fortalecimento social. Dessa forma, todos os outros agricultores que estao [cadastrados] somente na lista de presença começam a frequentar as atividades que [têm como objetivo] fazê-los se sentirem de fato socios. Consequentemente, a cooperativa ganha robustez. Se a cooperativa nao for forte, nao tiver autonomia, como é que ela vai fazer uma negociaçao comercial em parceria com uma grande empresa? Por isso, o foco que nos temos tido nesses quatro anos e pouco, quase cinco, é sempre fortalecer essas organizaçoes [as cooperativas]. Fortalecendo-as, elas se tornam fortes o suficiente para estar realizando novos negocios com outros parceiros, aumentando a geraçao de valor e tudo o mais. (INTERVIEW 02 ¶5).

> Na verdade, [os treinamentos sao o processo de] alinhamento. É quando a gente passa quais sao os padroes de qualidade, os padroes de fornecimento, as praticas de manejo que a gente considera mais adequadas para diminuir os impactos ambientais que, eventualmente, o [cultivo] possa causar. [O alinhamento também ocorre ao] fazermos o planejamento com eles do cronograma e do volume de fornecimento. Entao, é uma relaçao muito de parceria neste planejamento de fornecimento. Temos o interesse nisso, [pois assim] os subprodutos chegam aqui com qualidade, dentro dos prazos, da melhor forma possivel. E eles também tem o interesse [nisso], porque eles nao querem causar impactos ambientais negativos. [Além disso], querem ter o melhor rendimento no processo deles [para diminuir o] custo (INTERVIEW 03 ¶58).

After defining the “alignment management” category and its subcategories based on BIE data, the researcher carried out Step 3 of the analytical scheme depicted in Table 4. The entire collection of external sources was coded in order to identify evidence pertaining to “alignment management” and its subcategories. At Step 4, the literature dataset nodes were incorporated into a group query in NVivo 10 to validate the constructs. The group query identified internal sources that were associated with external sources in a specific way. The execution of the query resulted in the automatic generation of Graph 21.

Graph 21 – Group query results for the category “alignment management”




Source: Adapted by the author from NVivo 10.

Graph 21 demonstrates that the alignment management employed by OERM in the Benevides Industrial Ecosystem is comparable to the integration processes managed by coordinating organizations in the cases presented by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow, and Ehrenfeld (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010).

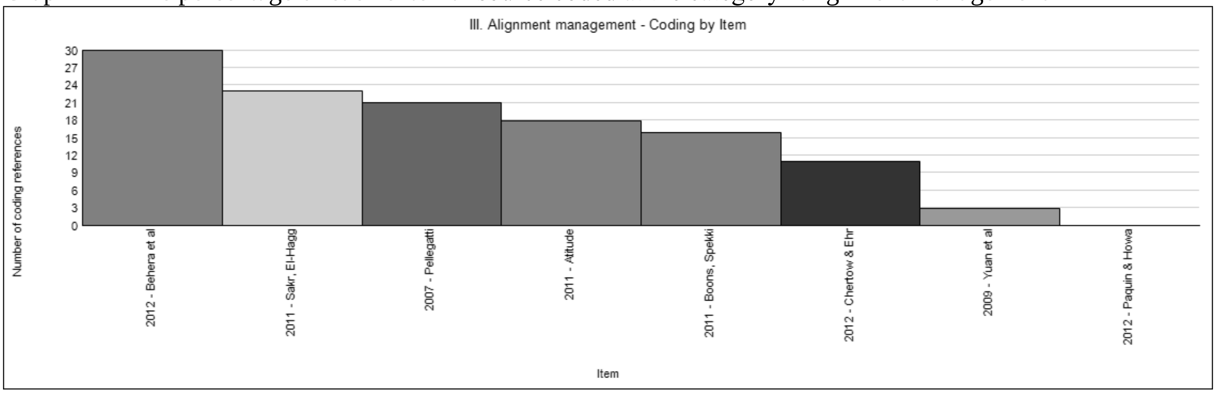
Table 22 presents the names of the external sources that were coded in the category "alignment management" and its subcategories, as well as the number of coded references and the proportion of the source represented by the coding. Graph 22 depicts the percentage of each source that has been coded.

Table 22 – The summary of the external source materials coded at the category "alignment management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2007 – Pellegatti | Internals\\Literature | 21 | 4.02% |
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 3 | 1.89% |
| PDF | 2011 – Atitude | Internals\\Literature | 18 | 6.34% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 16 | 2.74% |
| PDF | 2011 – Sakr *et al*. | Internals\\Literature | 23 | 2.85% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 30 | 4.77% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 11 | 1.59% |

Source: Adapted by the author from NVivo 10.

Graph 22 – The percentage of each external source coded at the category "alignment management"




Source: Adapted by the author from NVivo 10.

### *4.3.4 Industrial symbiosis management*

The evidence suggests that the category "industrial symbiosis management" refers to a process carried out by OEID to create the conditions that promote industrial symbiosis in order to more effectively achieve the sustainability objectives stated in the industrial ecosystem strategy. The favorable situation includes a policy and regulatory framework, infrastructure, financial support, green technology, and information sharing. In this context, industrial ecosystem members are accountable for the planning and execution of industrial symbioses. They develop and plan their IS strategy, align their employees, plan their operations, monitor the execution of IS, and adapt their IS strategy as necessary. It is also essential to note that industrial symbiosis extends beyond the recycling of by-products and wastes. Financial, stakeholder, process, and knowledge symbioses can be developed by businesses.

Table 23 displays the results of axial coding and selective coding for the category "industrial symbiosis management" and its subcategories within the dataset relating to the Benevides Industrial Ecosystem. It contains the number of sources used to measure this category and its subcategories, as well as the number of references to evidence that have been coded.

Table 23 – The category "industrial symbiosis management" and its subcategories

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| IV. Industrial symbiosis management | 20 | 493 | 02/07/2012 11:54 AM | LQ |
| 24. Development of industrial symbiosis strategy | 10 | 56 | 02/07/2012 12:17 PM | LQ |
| 25. Planning of symbioses | 15 | 140 | 02/07/2012 12:18 PM | LQ |
| 26. Definition of the human capital capabilities required | 5 | 21 | 02/07/2012 12:20 PM | LQ |
| 27. Definition of the technology enablers of the strategy | 3 | 18 | 02/07/2012 12:21 PM | LQ |
| 28. Alignment of employees with industrial symbiosis strat | 9 | 38 | 02/07/2012 12:21 PM | LQ |
| 29. Monitoring of execution of industrial symbiosis | 6 | 27 | 02/07/2012 12:22 PM | LQ |
| 30. Adaptation of industrial symbiosis strategy opportunely | 3 | 15 | 02/07/2012 12:22 PM | LQ |

Source: Adapted by the author from NVivo 10.

Table 24 displays the name of the internal sources that were coded for the category "industrial symbiosis management" and its subcategories, including the number of references that were coded and the percentage of the source that the coding represents.

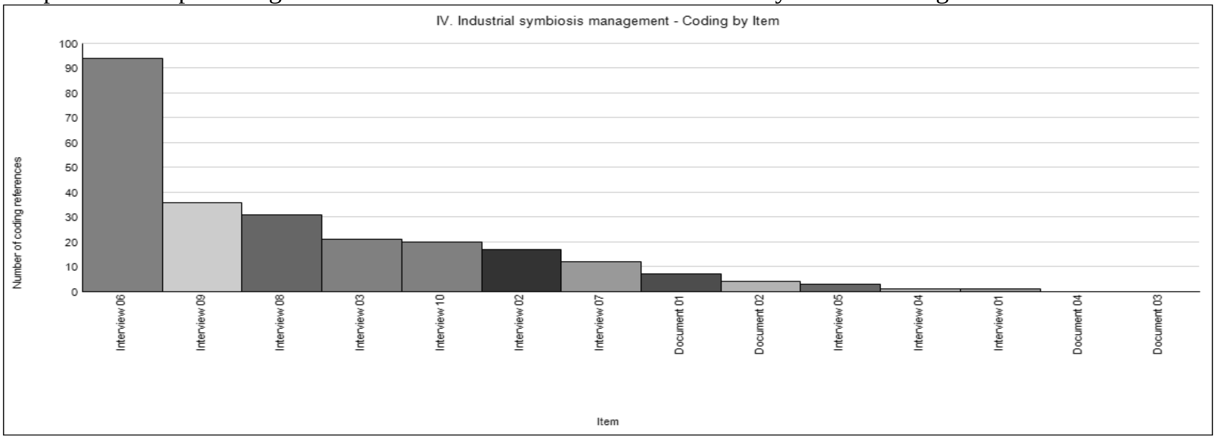
Table 24 – The summary of the internal source materials coded at the category "industrial symbiosis management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 7 | 4.66% |
| Document | Document 02 | Internals\\Documents | 4 | 4.33% |
| Transcript | Interview 01 | Internals\\Interviews | 1 | 0.40% |
| Transcript | Interview 02 | Internals\\Interviews | 17 | 5.75% |
| Transcript | Interview 03 | Internals\\Interviews | 21 | 6.67% |
| Transcript | Interview 04 | Internals\\Interviews | 1 | 0.81% |
| Transcript | Interview 05 | Internals\\Interviews | 3 | 3.20% |
| Transcript | Interview 06 | Internals\\Interviews | 94 | 36.79% |
| Transcript | Interview 07 | Internals\\Interviews | 12 | 12.47% |
| Transcript | Interview 08 | Internals\\Interviews | 31 | 13.87% |
| Transcript | Interview 09 | Internals\\Interviews | 36 | 18.18% |
| Transcript | Interview 10 | Internals\\Interviews | 20 | 12.25% |

Source: Adapted by the author from NVivo 10.

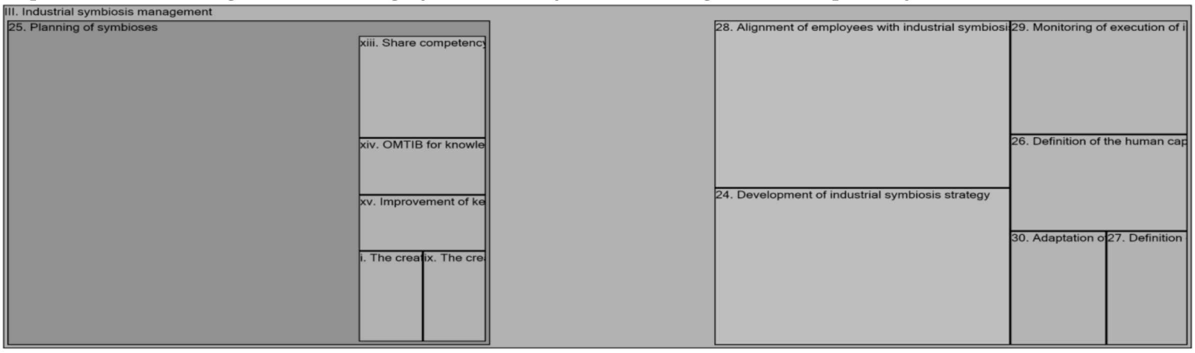
In Graph 23, the proportion of each source that has been coded is depicted graphically. Note that Interview 06 with the manager of Natura's Benevides Industrial Unit was the primary internal source that shaped the constructs. Graph 24 depicts a tree map with emerging subcategories compared by the number of coded references in order to display the most frequently discussed topics by interviewees. As observed, the subcategory "planning of industrial symbioses" was regarded as the most important process in industrial symbiosis management.

Graph 23 – The percentage of each internal source coded at “industrial symbiosis management”




Source: Adapted by the author from NVivo 10.

Graph 24 – The subcategories of the category “industrial symbiosis management” compared by number of coded references




Source: Adapted by the author from NVivo 10.

Here are some examples of internal references that were used to develop the “industrial symbiosis management” category and its subcategories:

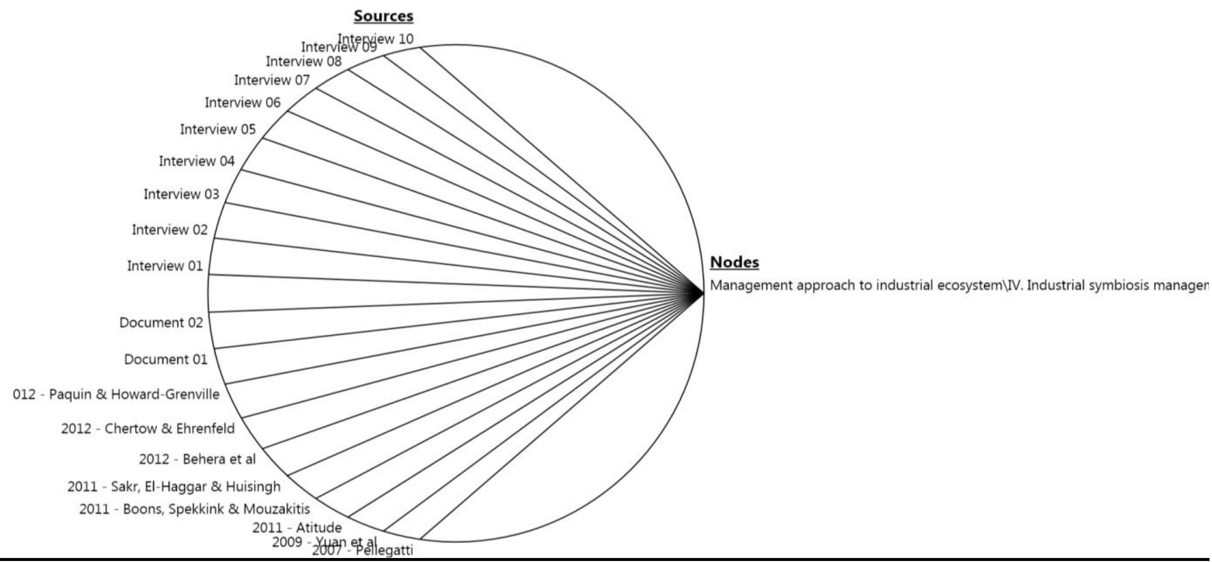
> Na verdade, a gente até brinca que aqui nao é uma fabrica de oleo, mas uma fabrica de residuos. A gente gera mais residuo do que oleo. A quantidade de oleo é muito pequena perto da quantidade de residuo que a gente chama de torta. O que a gente fez [para lidar com isso]? A gente fez uma parceria com a SEPLACque é um orgao do governo que tem o maior banco de germoplasma de cacau do mundo. Eles tinham um projeto de compostagem que foi desenvolvido por uns pesquisadores de la. O que a gente fez? A gente pegou a nossa torta, mandou para la. Eles fizeram, com caroços de açai e outros residuos que eles coletam de outros locais, uma compostagem. Depois fizeram uma analise e viram que aquilo era um adubo riquissimo. Entao, eles decidiram utilizar esse adubo no proprio plantio deles. Eles têm uma area imensa, pois é um banco de germoplasma imenso. Entao, a gente doa toda a nossa torta para esse orgao do governo (Simbiose industrial) que é um orgao do governo federal, mas que tem toda essa parte de pesquisa. A torta vem de todas as sementes, pois todas as sementes geram torta. Tudo o que gera oleo gera torta. Entao, eu tenho torta de cacau, de cupuaçu, de murumuru, tudo gera torta. O que é a torta? É o residuo desse processo de prensagem (INTERVIEW 06 ¶25).

> Simbiose industrial é a potencializaçao e a otimizaçao de recursos disponiveis numa cadeia. É ‘tirar agua de pedra’. É otimizar aquilo que a gente retira do meio ambiente. É otimizar o conhecimento disponivel. A gente tem aprendido que a simbiose industrial nao é so [uma questao de] residuo. A gente tem aprendido que simbiose industrial é um conceito de reutilizaçao, de aproveitamento, de otimizaçao de todos os recursos disponiveis numa operaçao. Isso permeia por tudo. Permeia por residuo

> sim, mas permeia por recurso de utilidades, como agua, energia, luz. É também otimizar os recursos de logistica. Simbiose é um conceito que deveria estar aplicado a tudo. Simbiose é uma visao holistica de empresas que têm o mesmo proposito de reduzir impacto ambiental, de reduzir impacto social, de otimizar recursos. A simbiose industrial vai trazer outros beneficios que talvez a gente ainda nao enxergue. Nao so financeiro que é o que a gente enxerga facil, pois é bem material. Tem o impacto de ambiente quando eu me refiro à otimizaçao de utilizaçao de carro que tem a ver com menos consumo de combustivel que, normalmente, é fossil. E tem o impacto social também, nessa questao, que é a gente poder usar o conhecimento de uma empresa em prol de outras entidades. Para mim, simbiose é um conceito muito mais amplo que residuos (INTERVIEW 08 ¶69).

The researcher completed Step 3 of the analytical scheme depicted in Table 4 after defining the category "industrial symbiosis management" and its subcategories using BIE data. The entire set of external sources was coded to identify data related to "industrial symbiosis management" and its subcategories. At Step 4, the nodes resulting from the literature dataset were added to a group query in NVivo 10 in order to validate the constructs. The group query identified internal sources that were associated with external sources in a specific way. Graph 25 was automatically generated using the query execution results.

Graph 25 – Group query results for the category "industrial symbiosis management"




Source: Adapted by the author from NVivo 10.

Graph 25 demonstrates that the OERM process for deliberately fostering industrial symbiosis at GRA is nearly equivalent to the approach to stimulating industrial symbiosis employed by coordinating organizations in the cases described by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010).

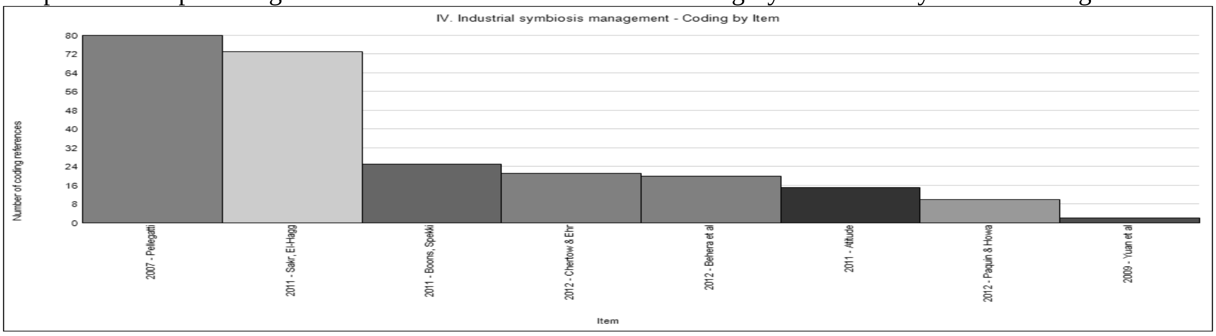
Table 25 displays the name of the external sources that were coded for the category "industrial symbiosis management" and its subcategories, including the number of references that validated them and the percentage of the source that coding represents. In Graph 26, there is a chart that illustrates the percentage of each source coded.

Table 25 – The summary of the external source materials coded at the category "industrial symbiosis management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2007 – Pellegatti | Internals\\Literature | 80 | 10.02% |
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 2 | 1.01% |
| PDF | 2011 – Atitude | Internals\\Literature | 15 | 4.86% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 25 | 4.41% |
| PDF | 2011 – Sakr *et al*. | Internals\\Literature | 73 | 9.34% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 20 | 3.49% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 21 | 3.02% |
| PDF | 2012 – Paquin and Howard-Grenville | Internals\\Literature | 10 | 1.78% |

Source: Adapted by the author from NVivo 10.

Graph 26 – The percentage of each external source coded at the category "industrial symbiosis management"




Source: Adapted by the author from NVivo 10.

### *4.3.5 Accountability management*

Examining the evidence, the category "accountability management" refers to a process of monitoring and learning through metric-based analysis of problems, barriers, and obstacles during industrial symbiosis implementation.

The researcher derived the category "accountability management" from the data using open coding and axial coding. Table 26 presents the data of the process of coding based on the category "accountability management" within the dataset information with respect to the Benevides Industrial Ecosystem. It combines the number of sources employed for measuring the category with the number of references coded for producing evidence.

Table 26 – The category "accountability management"

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| V. Accountability management | 16 | 119 | 02/07/2012 11:54 AM | LQ |
| 31. Monitor and learn about problems, barriers, a | 12 | 74 | 02/07/2012 12:36 PM | LQ |

Source: Adapted by the author from NVivo 10.

Table 27 displays the names of the internal sources that were coded at the category "accountability management," along with the number of references coded and the proportion of the source that the coding represents.

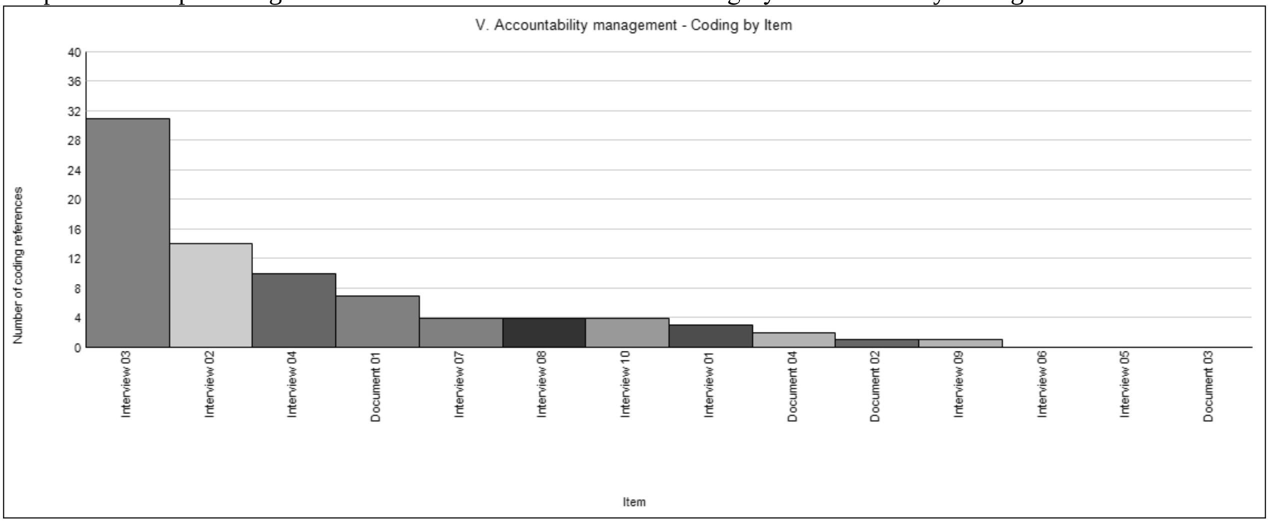
Table 27 – The summary of the internal source materials coded at the category "accountability management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 7 | 3.38% |
| Document | Document 02 | Internals\\Documents | 1 | 1.64% |
| Document | Document 04 | Internals\\Documents | 2 | 0.42% |
| Transcript | Interview 01 | Internals\\Interviews | 3 | 0.69% |
| Transcript | Interview 02 | Internals\\Interviews | 14 | 5.46% |
| Transcript | Interview 03 | Internals\\Interviews | 31 | 12.69% |
| Transcript | Interview 04 | Internals\\Interviews | 10 | 2.98% |
| Transcript | Interview 07 | Internals\\Interviews | 4 | 4.67% |
| Transcript | Interview 08 | Internals\\Interviews | 4 | 1.65% |
| Transcript | Interview 09 | Internals\\Interviews | 1 | 1.08% |
| Transcript | Interview 10 | Internals\\Interviews | 4 | 4.21% |

Source: Adapted by the author from NVivo 10.

There is a chart depicting the percentage of each source that was coded in Graph 27. Notably, Interview 03 with the coordinator of the eco-relationships team at OERM was the primary internal source that shaped the construct.

Graph 27 – The percentage of each internal source coded at the category "accountability management"




Source: Adapted by the author from NVivo 10.

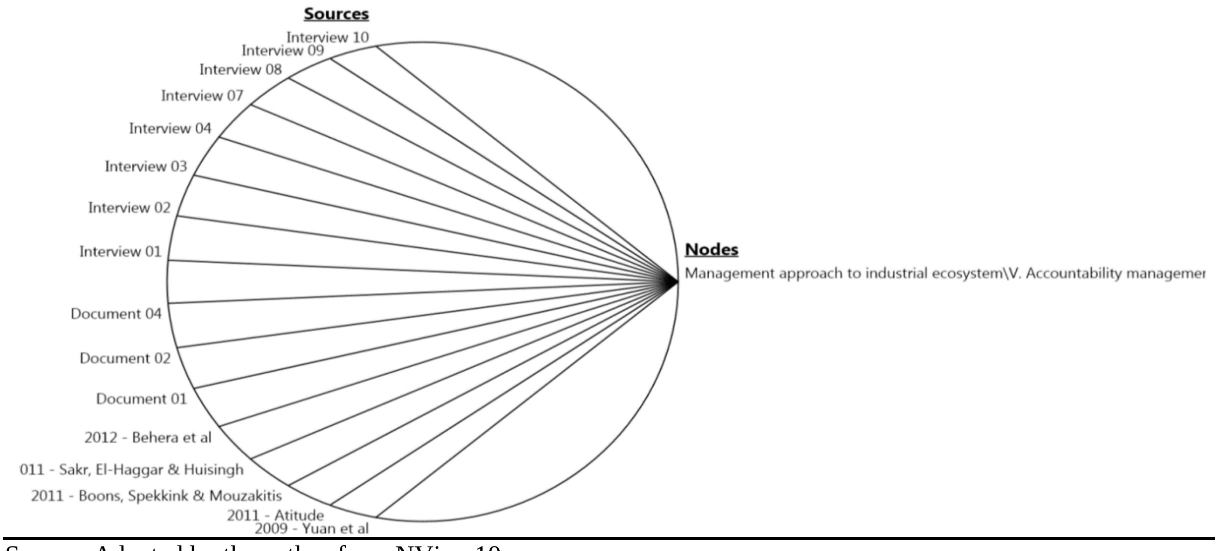
The following are examples of internal references that were used to shape the concept of "accountability management":

> A gente tem alguns indicadores [para o processo de] fornecimento. Temos duas grandes categorias de indicadores: recursos diretos e indiretos. Eles verificam o montante dos insumos da biodiversidade que a Natura trabalha. Ha indicadores de fornecimento, de fundos & apoio, de estruturas de assessorias e capacitaçoes. Estes sao alguns dos indicadores do modo em que estamos trabalhando a questao econômica. [Eles tratam de] como a gente esta alocando os recursos para trabalhar com as organizaçoes. Da maior parte dos recursos que a Natura desembolsou para essa tematica da biodiversidade, 90% esteve relacionado a fornecimento e produçao,

> ou seja, na compra desses produtos da biodiversidade. Isto envolve [também] custos de assessoria, capacitaçoes e treinamentos. E temos outro indicador que é o numero de fornecedores rurais que estao envolvidos no fornecimento para a Natura. Para este indicador, nos temos uma meta que é fazer todo um levantamento geografico para saber onde as familias estao localizadas (INTERVIEW 03 ¶60).
>
> Existe também um indicador, uma ferramenta institucional, que, além da UIB, a Natura toda que trabalha com biodiversidade usa. É o bioclicar, uma ferramenta que faz uma avaliaçao do fornecedor. [O] bio [trata dos aspectos] social, econômico e ambiental e o clicar [lida com] a parte de fornecimento, prazo de entrega, volume atingido. É uma ferramenta que a gente consegue avaliar em termos quantitativos [além de] toda uma analise qualitativa por tras. Com o bio, a Natura avalia: como esta a organizaçao [fornecedora] no sentido da comercializaçao nao so com a Natura, mas com o mercado em geral; como ela esta em termos de organizaçao; se ela é uma cooperativa ou associaçao, como ela esta em termos de participaçao dos associados; como ela esta em termos ambientais; se a area que ela esta inserida é uma area degradada ou nao, se tem manejo ou nao tem. É uma analise socio-economico-ambiental. O clicar faz uma analise do fornecimento propriamente dito. [Ele avalia] se a organizaçao cumpriu os prazos de entrega, se cumpriu o volume planejado, se ela tem uma rastreabilidade no fornecimento. Este indicador faz uma avaliaçao nestes dois cenarios (INTERVIEW 03 ¶66).

After defining the category "accountability management" based on BIE data, the researcher proceeded to Step 3 of the analytic scheme described in Table 4. The entirety of external sources was scoured for evidence that matched the category "accountability management." The literature dataset nodes were utilized in a group query using NVivo 10 at Step 4 to validate the construct. As a result, the group query identified internal sources associated with external ones in a specific manner. After the query was executed, the results were automatically displayed in Graph 28.

Graph 28 – Group query results for the category "accountability management"




Source: Adapted by the author from NVivo 10.

Graph 28 demonstrates that OERM's process of monitoring and learning by metrics about problems, barriers, and challenges in implementing industrial symbiosis at BIE is comparable to monitoring processes used by coordinating organizations in the initiatives highlighted by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Sakr *et al*. (2011), and Yuan *et al*. (2010).

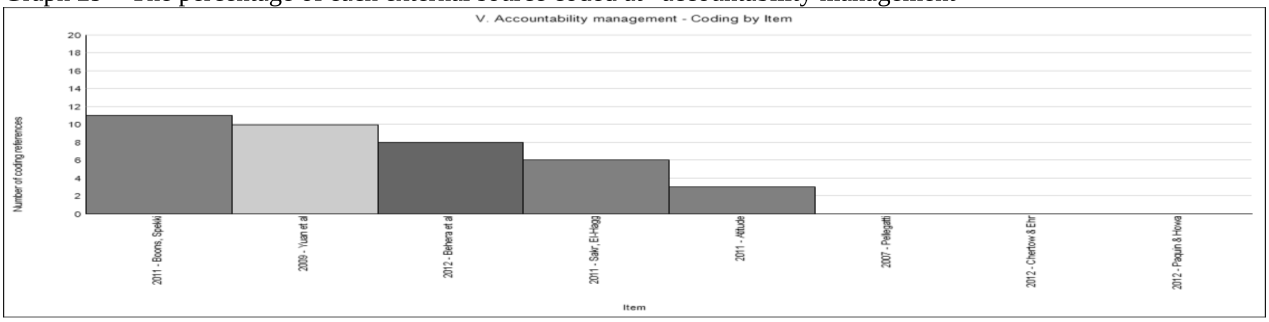
Table 28 displays the name of the external sources that were coded in the category "accountability management," including the number of references that validated it and the percentage of the source that coding represents. In Graph 29, there is a chart that illustrates the percentage of each source coded.

Table 28 – The summary of the external source materials coded at the category "accountability management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 10 | 4.44% |
| PDF | 2011 – Atitude | Internals\\Literature | 3 | 1.41% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 11 | 3.04% |
| PDF | 2011 – Sakr *et al*. | Internals\\Literature | 6 | 0.67% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 8 | 1.09% |

Source: Adapted by the author from NVivo 10.

Graph 29 – The percentage of each external source coded at "accountability management"




Source: Adapted by the author from NVivo 10.

### *4.3.6 System adaptation management*

Based on the evidence available, the category "system adaptation management" corresponds to the use of internal operational data and new external environmental and competitive data to test and adapt the industrial ecosystem strategy, thereby initiating a new loop around strategy planning and operational execution. This process is analogous to the resilience of natural ecosystems.

Using open coding and axial coding, the researcher extracted the category "system adaptation management" from the collected data. Table 29 displays the results of the process of coding based on the category "system adaption management" within the dataset pertaining to the Benevides Industrial Ecosystem. It combines the number of sources used for assessing the category with the number of references coded for producing evidence.

Table 29 – The category "system adaptation management"

| Name | Sources | References | Created On | Created By |
|---|---|---|---|---|
| VI. System adaptation management | 16 | 62 | 02/07/2012 11:55 AM | LQ |
| 32. Use of internal operational data and new ext | 4 | 25 | 02/07/2012 12:37 PM | LQ |

Source: Adapted by the author from NVivo 10.

Table 30 exhibits the names of the internal sources that were coded under the category "system adaptation management," as well as the number of references coded and the proportion of the source that the coding represents.

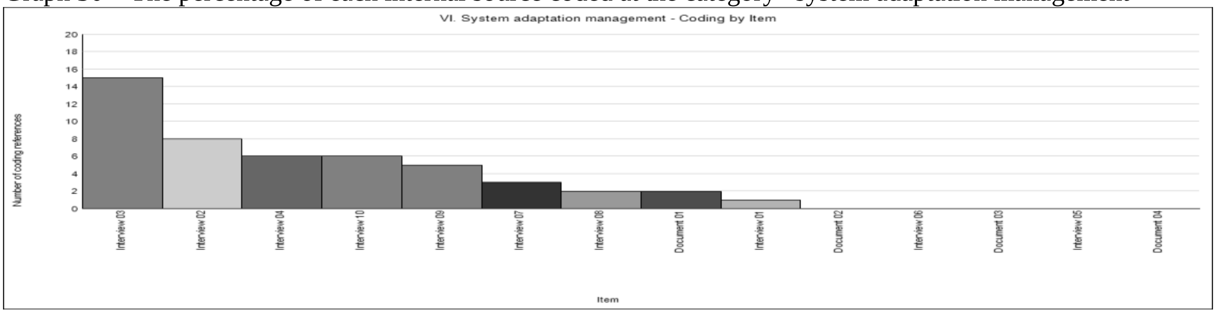
Table 30 – The summary of the internal source materials coded at the category "system adaptation management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| Document | Document 01 | Internals\\Documents | 2 | 1.95% |
| Transcript | Interview 01 | Internals\\Interviews | 1 | 0.59% |
| Transcript | Interview 02 | Internals\\Interviews | 8 | 2.80% |
| Transcript | Interview 03 | Internals\\Interviews | 15 | 7.29% |
| Transcript | Interview 04 | Internals\\Interviews | 6 | 1.57% |
| Transcript | Interview 07 | Internals\\Interviews | 3 | 3.48% |
| Transcript | Interview 08 | Internals\\Interviews | 2 | 1.07% |
| Transcript | Interview 09 | Internals\\Interviews | 5 | 3.60% |
| Transcript | Interview 10 | Internals\\Interviews | 6 | 6.45% |

Source: Adapted by the author from NVivo 10.

In Graph 30, the percentage of each source that was coded is showcased. Note that Interview 03 with the coordinator of the eco-relationships analyst team at OERM was the primary internal source that shaped the construct.

Graph 30 – The percentage of each internal source coded at the category "system adaptation management"




Source: Adapted by the author from NVivo 10.

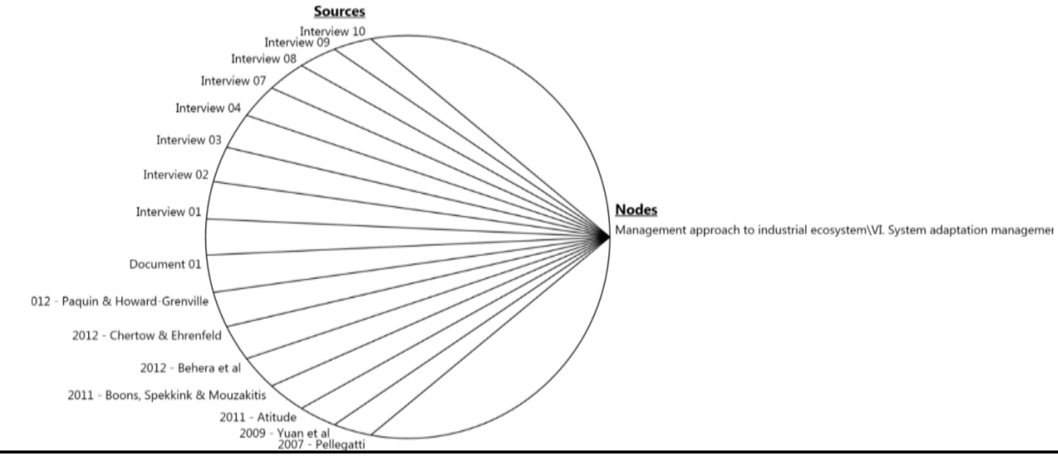
Here are a few examples of internal sources that helped shape the concept of "system adaptation management":

> Ao final de cada ano, a gente tem uma avaliaçao de fornecimento. A gente faz uma avaliaçao de como foi o fornecimento ao longo do ano. Damos algum retorno para eles [sobre] qual foi o volume, como foi a entrega, como foi o cronograma de entrega, como a gente pode melhorar, o que é que teve de investimento em cada um dos indicadores. Entao, a gente faz todo um trabalho de avaliaçao que aí ja é um pré-planejamento para o ano seguinte. O foco é, ao final de cada ano, fazer uma avaliaçao do fornecimento baseada nos indicadores. Damos um retorno para eles, pois a gente quer ouvir como é que eles estao vendo esses investimentos, principalmente, porque a gente trabalha com estudos e assessorias e investimentos em infraestrutura. [Queremos saber] se isso traz

> impacto positivo ou nao para eles. É meio que uma avaliaçao conjunta do nosso relacionamento com eles e deles com a gente (INTERVIEW 03 ¶64).
>
> Muda, porque mudam as pessoas também. [A estabilidade] nao existe nem tem como existir. Consequentemente, esse ecossistema nunca vai ser uma coisa estatica e estabilizada. [Ha constantes] adaptaçoes do modelo, da relaçao comercial, da relaçao de parceria (INTERVIEW 02 ¶100).
>
> Nos temos um ciclo [que finaliza no final] do ano. No ciclo de parcerias, de relacionamentos, nao ha um fechamento, ha sempre adaptaçoes. [Isso acontece] aleatoriamente. Seria um fechamento se nos tivessemos definido numa estratégia que, no ano tal, nos nao vamos mais querer se relacionar com a cooperativa tal, porque nos nao temos mais interesse naquele negocio. Isso ainda nao aconteceu, mas nao significa que um dia nao possa acontecer. [Isto] seria o fim de uma relaçao comercial com uma das cooperativas por algum motivo, [como a falta de] interesse naquele insumo. Nos temos estratégias para que, se isso vier a acontecer, seja de forma lenta, [dando às] cooperativas um tempo de conseguir novos mercados (INTERVIEW 02 ¶102).

After defining the category "system adaptation management" based on BIE data, the researcher carried out Step 3 of analytic scheme in Table 4. All external sources were coded to identify evidence-based data comparable to the concept "system adaptation management." In Step 4, the literature dataset nodes were employed in a group query using NVivo 10. Consequently, the group query identified internal sources that were specifically associated with external sources. Graph 31 automatically displayed the results once the query was executed.

Graph 31 – Group query results for the category "system adaptation management"




Source: Adapted by the author from NVivo 10.

Graph 31 demonstrates that OERM's process of adapting the Benevides Industrial Ecosystem is directly analogous to industrial ecosystem adaptation processes utilized by coordinating organizations in initiatives showcased by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), and Yuan *et al*. (2010).

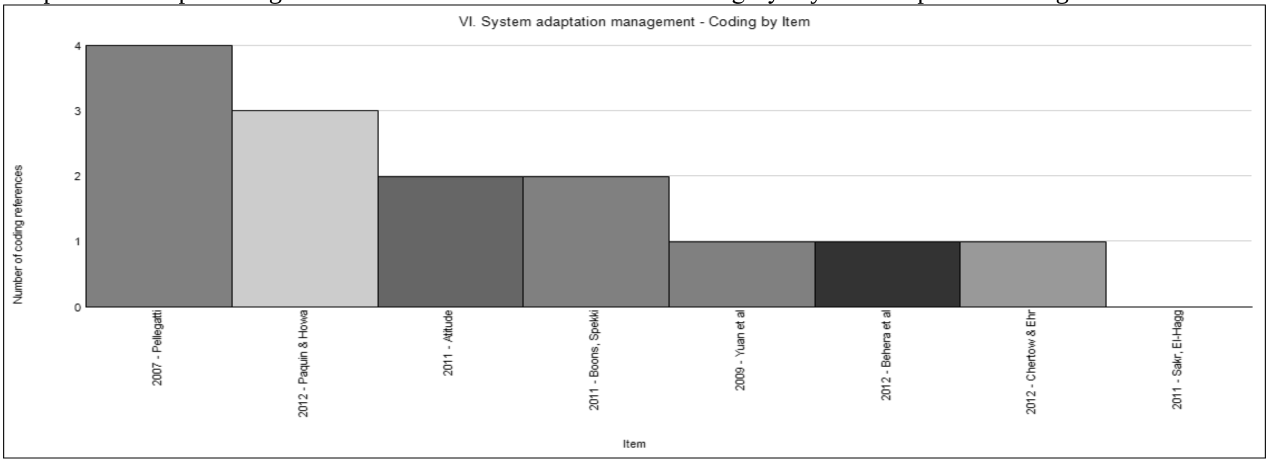
Table 31 lists the external sources that were coded for the category "system adaptation management," along with the number of references that validated it and the percentage of the source that coding represents. There is a chart depicting the percentage of each source that has been coded in Graph 32.

Table 31 – The summary of the external source materials coded at the category "system adaptation management"

| Type | Name | In Folder | References | Coverage |
|---|---|---|---|---|
| PDF | 2007 – Pellegatti | Internals\\Literature | 4 | 0.40% |
| PDF | 2009 – Yuan *et al*. | Internals\\Literature | 1 | 0.20% |
| PDF | 2011 – Atitude | Internals\\Literature | 2 | 1.31% |
| PDF | 2011 – Boons, Spekkink and Mouzakitis | Internals\\Literature | 2 | 0.40% |
| PDF | 2012 – Behera *et al*. | Internals\\Literature | 1 | 0.21% |
| PDF | 2012 – Chertow and Ehrenfeld | Internals\\Literature | 1 | 0.20% |
| PDF | 2012 – Paquin and Howard-Grenville | Internals\\Literature | 3 | 0.30% |

Source: Adapted by the author from NVivo 10.

Graph 32 – The percentage of each external source coded at the category "system adaptation management"




Source: Adapted by the author from NVivo 10.

## 4.4 Identifying relationships between constructs

An important part of qualitative research is a thorough examination of the "relationships" among constructs. To this end, the researcher employed "selective coding" to explore relationships between categories and subcategories presented in Table 10. Glaser and Strauss (1967) and Strauss and Corbin (2008) define selective coding as the technique of choosing a fundamental category, methodically linking it to other categories, confirming those relationships, and completing categories that need additional refinement and development. They emphasize that the basic category is the phenomenon to which all other categories are related. In the present study, selective coding was the last step in building the proposed theoretical framework[47], where the researcher connected all categories and subcategories together around one core category, “the management of eco-industrial development.” This final building process aimed at (i) integrating all constructs, which were treated as stages of MEID, and (ii) refining the emerging framework.

The main outcomes of the selective coding procedure applied in this research were relationships, which are “axioms” or “propositions” that define the connection between two or more constructs. The researcher put them in the form of “relational statements” to make assumptions about how the emerging constructs from the exploration of MEID are connected. When using selective coding, the researcher assumed and validated a series of relational statements to demonstrate how MEID concepts are related. In this thesis, relational statements express associations and relational dynamics between a category (treated as a sub-process of the management approach to EID) and a subcategory (regarded as a supporting activity of a sub-process)—for example, the subcategory “definition of the technology enablers of the strategy” is a supporting activity for the category “industrial ecosystem strategy development.” Relational statements also represent relations between two categories—for example, the category “the office of eco-relationships management” and the category “the management approach to the industrial ecosystem.”

The relational statements that were built and validated by the researcher are made up of three parts in conformity with NVivo: “from,” “to,” and “type”—for example, “the office of eco-relationships management” (from) “executes” (type) “the management approach to the industrial ecosystem” (to). According to QSR International (2011), the terms “from” and “to” refer to the constructs that are involved in the relationship, while the nature of relational statements is indicated by a “type.” Relationship types classify the relational statements and allow for comparisons between all the relationships of a particular type (QSR INTERNATIONAL, 2011). Relationship types have both a name and a direction. In this study, the names of relationship types are a verb or verbal expression—for example, “executes” or “is associated with.” Verbal relationship type names assist because they make it clear what is being stated, clarify the relationship type’s direction, and indicate what constructs are “from” and “to” (QSR INTERNATIONAL, 2011).

When the researcher defined each relationship type, he gave it a direction represented by a connector. NVivo provided three directions and their corresponding connectors to use, each giving different meanings to the relationships the researcher formulated: (i) Associative (——);

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[47] Once the theory-building phase was done, the researcher did the theory validation procedure, which is shown in Table 4 as Steps 3 and 4.

(ii) One way (⟶); and (iii) Symmetrical (⟷) (QSR INTERNATIONAL, 2011). An "associative relationship" was used to demonstrate that constructs are co-occurrences of certain phenomena or correlations of various strengths—for example, "strategic analysis 'guides' formulation of strategy." They are represented just by a connector without arrowheads to link constructs. A "one-way relationship" was used to demonstrate a relationship between constructs which has a definite direction of causation, an agent and a recipient—for example, "the office of eco-relationships management 'executes' the management approach to the industrial ecosystem." A one-way relationship is represented by a causal connector that uses an arrow at one end or the other. A "symmetrical relationship" is used to demonstrate a two-way interaction between the constructs. A reciprocal connector with an arrow at each end serves as a representation for this relationship, which describes something that two constructs do for one another (QSR INTERNATIONAL, 2011). The researcher did not identify a relationship of this kind.

In practical terms, the researcher applied a multi-step process of selective coding using NVivo according to Leech and Onwuegbuzie's (2007; 2008; 2011) procedural suggestions. That qualitative data analysis software enabled him to formulate a range of relational statements and take references (sentences) out of the collected data to validate 35 of those axioms. First, the researcher selected the construct "management of eco-industrial development" as the one big idea that could capture a recurring trend in the BIE dataset. Afterwards, he read the references coded at nodes in order to identify possible connections between the overarching category and the rest of the categories, among categories, and between categories and subcategories (find them in Table 10). For each potential connection, the researcher specified the "from" construct, defined a relationship direction (association, causal in either direction, or reciprocated), determined a relationship type (a verb or verbal expression), and specified the "to" construct. At the last step, he coded information from the BIE dataset to confirm the connections he thought were there.

As he went through his sources, the researcher could code information about assumed connections that supported or proved relational statements. The researcher used coding queries[48] to verify probable linkages between the core category and categories, across categories, and between categories and subcategories. Through coding queries, the researcher collected phrases coded at nodes associated with core category, categories and subcategories—for instance, material coded at "industrial ecosystem strategy development" and "description of the

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[48] Queries provide a versatile method for collecting and examining subsets of data. One may perform "coding queries" in NVivo in order to locate all material coded at certain nodes, a mixture of nodes, or a combination of nodes.

technological enablers of the strategy"—and examined associations and relational dynamics. The researcher also used operators to make the coding queries even more specific. For example, references coded as "formulation of strategy" that match information coded as "mechanisms for cluster growth" were used to narrow the search. Following this, sentences obtained from the coding query were analyzed for evidence. It produced the 35 relational statements given in Tables 32 and 33. It brings together the number of sources used for verifying relational statements and the number of references coded for building evidence.

Table 32 – Coding query results for types of relational statements

| | (Sub)category A | Type | (Sub)category B | Sources | References | Created On |
|---|---|---|---|---|---|---|
| **Relationship 1** | The office of eco-industrial management | *Executes* | Management approach to industrial ecosystem | 2 | 7 | 10/07/2012 9:45 AM |
| **Relationship 2** | Management approach to industrial ecosystem | *Brings about* | Features of industrial ecosystem | 11 | 50 | 10/07/2012 9:38 AM |
| **Relationship 3** | Industrial ecosystem strategy development | *Requires* | Alignment management | 7 | 13 | 10/07/2012 10:34 AM |
| **Relationship 4** | Industrial ecosystem strategy | *Shapes* | Development of industrial symbiosis strategy | 10 | 17 | 10/07/2012 10:19 AM |
| **Relationship 5** | Clarification of mission, values and vision | *Delimits* | Strategic analysis | 13 | 34 | 10/07/2012 11:44 AM |
| **Relationship 6** | Clarification of mission, values and vision | *Directs* | Strategy for industrial ecosystem development | 13 | 33 | 10/07/2012 11:45 AM |
| **Relationship 7** | Clarification of mission, values and vision | *Is based on* | Theoretical background for industrial ecosystem development | 13 | 31 | 10/07/2012 11:45 AM |
| **Relationship 8** | Clarification of mission, values and vision | *Points* | Industrial ecosystem goal | 2 | 2 | 10/07/2012 10:20 AM |
| **Relationship 9** | Strategic analysis | *Guides* | Formulation of strategy | 5 | 10 | 10/07/2012 11:46 AM |
| **Relationship 10** | Definition of the extent of industrial ecosystem | *Controls* | Primary components | 3 | 4 | 10/07/2012 11:47 AM |
| **Relationship 11** | Definition of the extent of industrial ecosystem | *Determines* | Primary components' functions | 2 | 2 | 10/07/2012 11:47 AM |
| **Relationship 12** | Definition of the extent of industrial ecosystem | *Depends on* | Secondary components | 2 | 4 | 10/07/2012 11:48 AM |
| **Relationship 13** | Definition of the extent of industrial ecosystem | *Relies on* | Secondary components' functions | 7 | 14 | 10/07/2012 11:49 AM |
| **Relationship 14** | Choosing of social issues to address through industrial ecosystem | *Affects* | Homeostasis in an industrial ecosystem | 4 | 4 | 10/07/2012 11:49 AM |
| **Relationship 15** | Formulation of strategy | *Forms* | Description of industrial ecosystem | 6 | 10 | 10/07/2012 12:00 PM |
| **Relationship 16** | Formulation of strategy | *Leads to* | Industrial ecosystem development | 9 | 26 | 10/07/2012 12:01 PM |
| **Relationship 17** | Formulation of strategy | *Invents* | Mechanisms for cluster development | 8 | 15 | 10/07/2012 11:58 AM |
| **Relationship 18** | Definition of CSR instruments | *Restricts* | Direct mechanisms | 9 | 27 | 10/07/2012 11:58 AM |
| **Relationship 19** | Definition of CSR instruments | *Limits* | Indirect mechanisms | 3 | 3 | 10/07/2012 11:59 AM |
| **Relationship 20** | Definition of CSR instruments | *Impacts* | Conservation of ecosystem services | 4 | 9 | 10/07/2012 10:27 AM |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Relationship 21** | OMTIB for creating learning and growth | *Is associated with* | OMTIB for integrating practices | 5 | 6 | 10/07/2012 10:29 AM |
| **Relationship 22** | OMTIB for integrating practices | *Is associated with* | OMTIB for creating a social dimension to the value proposition | 5 | 9 | 10/07/2012 10:31 AM |
| **Relationship 23** | OMTIB for creating a social dimension to the value proposition | *Results in* | Shareholder value | 3 | 8 | 10/07/2012 9:39 AM |
| **Relationship 24** | Alignment management | *Conduces to* | Industrial symbiosis management | 12 | 36 | 10/07/2012 10:32 AM |
| **Relationship 25** | Formal communication process of industrial ecosystem strategy | *Conduces to* | Industrial symbiosis management | 13 | 56 | 10/07/2012 10:32 AM |
| **Relationship 26** | Supporting organizations that operate within the industrial ecosystem | *Conduces to* | Industrial symbiosis management | 9 | 17 | 10/07/2012 9:42 AM |
| **Relationship 27** | Industrial symbiosis management | *Requires* | Accountability management | 5 | 11 | 10/07/2012 10:37 AM |
| **Relationship 28** | Development of industrial symbiosis strategy | *Requires* | Alignment of employees with industrial symbiosis strategy | 2 | 2 | 10/07/2012 10:47 AM |
| **Relationship 29** | Planning of symbioses | *Requires* | Monitoring of execution of industrial symbiosis | 4 | 5 | 10/07/2012 10:44 AM |
| **Relationship 30** | Alignment of employees with industrial symbiosis strategy | *Enables* | Planning of symbioses | 3 | 3 | 10/07/2012 10:48 AM |
| **Relationship 31** | Monitoring of execution of industrial symbiosis | *Provides* | Data to adaptation of industrial symbiosis strategy opportunely | 7 | 11 | 10/07/2012 9:43 AM |
| **Relationship 32** | Accountability management | *Leads to* | System adaptation management | 5 | 6 | 10/07/2012 11:43 AM |
| **Relationship 33** | Accountability management | Conducts | Assessment of industrial ecosystem development | 6 | 8 | 10/07/2012 10:50 AM |
| **Relationship 34** | Monitor and learn about problems, barriers, and challenges by metrics | *Checks* | Industrial symbiosis management | 6 | 10 | 10/07/2012 9:44 AM |
| **Relationship 35** | System adaptation management | *Readjusts* | Industrial ecosystem strategy | 7 | 31 | 10/07/2012 10:57 AM |

Source: Adapted by the author from NVivo 10.

Table 33 – Coding query results for directions of relational statements

| | (Sub)category A | Direction | (Sub)category B | Sources | References | Created On |
|---|---|---|---|---|---|---|
| **Relationship 1** | The office of eco-industrial management | ——— | Management approach to industrial ecosystem | 2 | 7 | 10/07/2012 9:45 AM |
| **Relationship 2** | Management approach to industrial ecosystem | → | Features of industrial ecosystem | 11 | 50 | 10/07/2012 9:38 AM |
| **Relationship 3** | Industrial ecosystem strategy development | ——— | Alignment management | 7 | 13 | 10/07/2012 10:34 AM |
| **Relationship 4** | Industrial ecosystem strategy | → | Development of industrial symbiosis strategy | 10 | 17 | 10/07/2012 10:19 AM |
| **Relationship 5** | Clarification of mission, values and vision | ——— | Strategic analysis | 13 | 34 | 10/07/2012 11:44 AM |
| **Relationship 6** | Clarification of mission, values and vision | ——— | Strategy for industrial ecosystem development | 13 | 33 | 10/07/2012 11:45 AM |
| **Relationship 7** | Clarification of mission, values and vision | ← | Theoretical background for industrial ecosystem development | 13 | 31 | 10/07/2012 11:45 AM |
| **Relationship 8** | Clarification of mission, values and vision | ——— | Industrial ecosystem goal | 2 | 2 | 10/07/2012 10:20 AM |
| **Relationship 9** | Strategic analysis | ——— | Formulation of strategy | 5 | 10 | 10/07/2012 11:46 AM |
| **Relationship 10** | Definition of the extent of industrial ecosystem | → | Primary components | 3 | 4 | 10/07/2012 11:47 AM |
| **Relationship 11** | Definition of the extent of industrial ecosystem | → | Primary components' functions | 2 | 2 | 10/07/2012 11:47 AM |

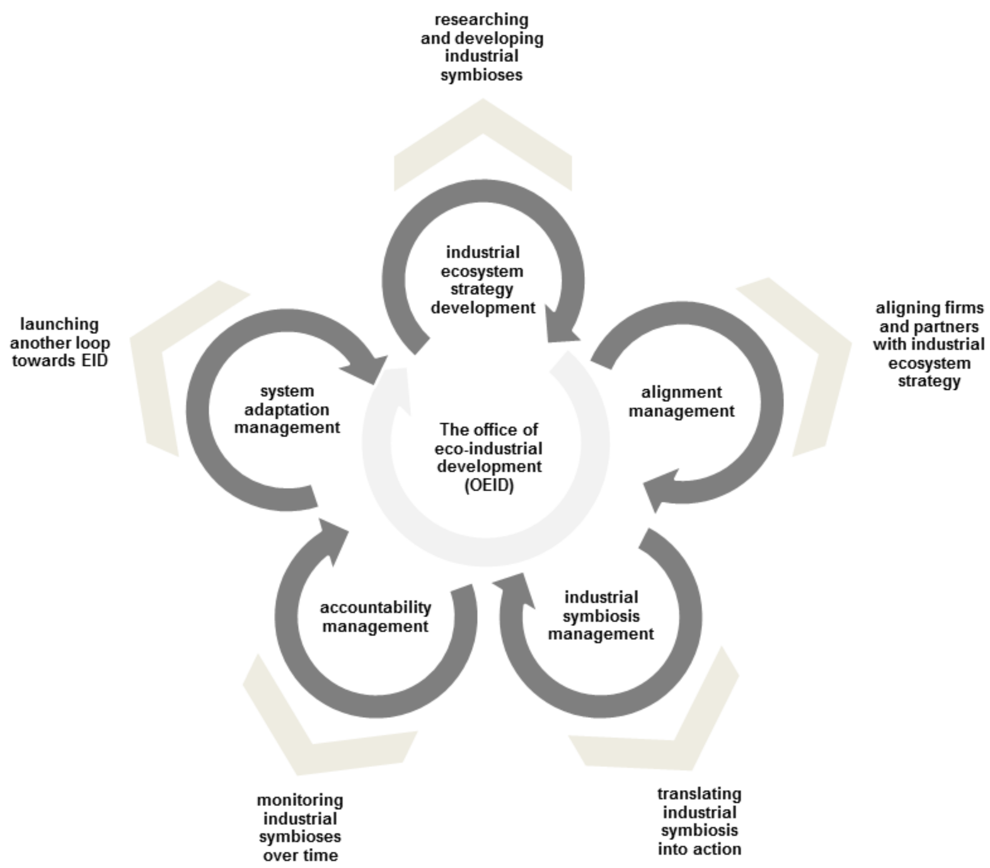
| | | | | | | |
|---|---|---|---|---|---|---|
| **Relationship 12** | Definition of the extent of industrial ecosystem | ← | Secondary components | 2 | 4 | 10/07/2012 11:48 AM |
| **Relationship 13** | Definition of the extent of industrial ecosystem | ← | Secondary components' functions | 7 | 14 | 10/07/2012 11:49 AM |
| **Relationship 14** | Choosing of social issues to address through industrial ecosystem | → | Homeostasis in an industrial ecosystem | 4 | 4 | 10/07/2012 11:49 AM |
| **Relationship 15** | Formulation of strategy | → | Description of industrial ecosystem | 6 | 10 | 10/07/2012 12:00 PM |
| **Relationship 16** | Formulation of strategy | → | Industrial ecosystem development | 9 | 26 | 10/07/2012 12:01 PM |
| **Relationship 17** | Formulation of strategy | → | Mechanisms for cluster development | 8 | 15 | 10/07/2012 11:58 AM |
| **Relationship 18** | Definition of CSR instruments | — | Direct mechanisms | 9 | 27 | 10/07/2012 11:58 AM |
| **Relationship 19** | Definition of CSR instruments | — | Indirect mechanisms | 3 | 3 | 10/07/2012 11:59 AM |
| **Relationship 20** | Definition of CSR instruments | → | Conservation of ecosystem services | 4 | 9 | 10/07/2012 10:27 AM |
| **Relationship 21** | OMTIB for creating learning and growth | — | OMTIB for integrating practices | 5 | 6 | 10/07/2012 10:29 AM |
| **Relationship 22** | OMTIB for integrating practices | — | OMTIB for creating a social dimension to the value proposition | 5 | 9 | 10/07/2012 10:31 AM |
| **Relationship 23** | OMTIB for creating a social dimension to the value proposition | → | Shareholder value | 3 | 8 | 10/07/2012 9:39 AM |
| **Relationship 24** | Alignment management | → | Industrial symbiosis management | 12 | 36 | 10/07/2012 10:32 AM |
| **Relationship 25** | Formal communication process of industrial ecosystem strategy | → | Industrial symbiosis management | 13 | 56 | 10/07/2012 10:32 AM |
| **Relationship 26** | Supporting organizations that operate within the industrial ecosystem | → | Industrial symbiosis management | 9 | 17 | 10/07/2012 9:42 AM |
| **Relationship 27** | Industrial symbiosis management | — | Accountability management | 5 | 11 | 10/07/2012 10:37 AM |
| **Relationship 28** | Development of industrial symbiosis strategy | — | Alignment of employees with industrial symbiosis strategy | 2 | 2 | 10/07/2012 10:47 AM |
| **Relationship 29** | Planning of symbioses | — | Monitoring of execution of industrial symbiosis | 4 | 5 | 10/07/2012 10:44 AM |
| **Relationship 30** | Alignment of employees with industrial symbiosis strategy | — | Planning of symbioses | 3 | 3 | 10/07/2012 10:48 AM |
| **Relationship 31** | Monitoring of execution of industrial symbiosis | → | Data to adaptation of industrial symbiosis strategy opportunely | 7 | 11 | 10/07/2012 9:43 AM |
| **Relationship 32** | Accountability management | — | System adaptation management | 5 | 6 | 10/07/2012 11:43 AM |
| **Relationship 33** | Accountability management | — | Assessment of industrial ecosystem development | 6 | 8 | 10/07/2012 10:50 AM |
| **Relationship 34** | Monitor and learn about problems, barriers, and challenges by metrics | — | Industrial symbiosis management | 6 | 10 | 10/07/2012 9:44 AM |
| **Relationship 35** | System adaptation management | → | Industrial ecosystem strategy | 7 | 31 | 10/07/2012 10:57 AM |

Source: Adapted by the author from NVivo 10.

## 5 THE THEORETICAL FRAMEWORK

The purpose of this chapter is to set out the theoretical framework for the management of eco-industrial development (MEID), which was meticulously constructed using Eisenhardt's (1989) eight-step procedure for developing theory from case study. The resulting framework from the theory-building process, shown in Figure 9, identifies MEID, develops its conceptualization, and connects it systematically to a range of constructs. This innovative concept in the field of industrial ecology is the outcome of a process of coding a dataset generated by a case study of the Benevides Industrial Ecosystem in order to gather evidence of the management process of EID. The generalization of the proposed conceptual framework for MEID is based on its similarity to industrial ecosystem management approaches used by world-renowned eco-industrial development initiatives depicted by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010).

Figure 9 – Theoretical framework for the management of eco-industrial development




Source: Adapted by the author from data analysis.

In conformity with the double hermeneutic approach expounded by Giddens (1984)[49], the proposed theoretical framework is derived from interviews with managers in which they provided lay discourse, and it is hoped that the assumptions and theoretical statements presented here will become an integral part of that discourse, thereby irreversibly altering it. As expected for the last stage of double hermeneutic, the formulated conceptual definition of MEID brings knowledge that can be appropriated by managers themselves and subsequently reapplied as part of their discourse and management approach. Accordingly, the framework introduced in this study is likely to have practical consequences for eco-industrial development. Despite this contribution, it is essential to emphasize that the proposed conceptual definition of MEID is inherently unstable in view of the limited knowledge (or beliefs) that the managers interviewed have about the circumstances of their own decisions, actions, and attitudes towards eco-industrial development.

The theoretical framework defined in this chapter describes the evolution of EID management over time in response to contextual changes. As discussed in greater detail in Subsection 5.1, the actions of pro-environmental managers toward EID constitute a strategic management process undertaken in response to the pursuit of private benefits, albeit with the intent to generate positive externalities. Subsection 5.2 demonstrates consistently that the office of eco-industrial development is in charge of implementing MEID. As part of putting this management system into place, there are five sub-processes: (i) developing an industrial ecosystem strategy; (ii) managing alignment; (iii) managing industrial symbiosis; (iv) managing accountability; and (v) managing system adaptation.

## 5.1 Management of eco-industrial development

According to the analyzed data, an industrial ecosystem is an economic system resulting from business managers' pro-environmental decisions, actions, and attitudes. Their environmentally friendly actions are known as "management of eco-industrial development." It consists of deliberate strategic decisions made to achieve the sustainability-profitability tradeoff through the formation, maintenance, and expansion of an industrial ecosystem. In ontological terms, MEID acts to align a community of businesses with environmentally friendly

[49] Subsection 2.1 has more information about how Giddens's (1984) double hermeneutic approach was used to build the proposed theoretical framework.

social norms[50] in order to sustain their financial growth. They consist of a cognitive framework that organizes human activities within a social system in a manner that minimizes the negative environmental impact. Therefore, managers ensure the viability or growth of their organizations by adhering to social norms that are environmentally friendly.

Semi-structured interviews, document gathering, and non-participant observations led the researcher to understand MEID as a strategic action taken in response to the pursuit of private benefits, albeit with the intention of creating positive externalities. Over the course of MEID implementation, managers adhering to pro-environmental social norms seek “cost reductions,” such as through the use of byproducts from neighboring factories, “revenue enhancement” through a price premium derived from an eco-friendly brand identity, or “business expansion” through access to dependable suppliers. Also, getting these results has important social, economic, and environmental benefits for the surrounding community and natural ecosystems.

These private benefits and positive externalities are directly attributable to industrial symbioses between firms in an industrial ecosystem. Note that industrial symbiosis is a fundamental mechanism for firms to align with environmentally friendly social norms for financial reasons. Despite the importance of industrial symbiosis to the development of a new model of production and trade that is beneficial to society and natural ecosystems, pro-environmental managers still face a number of problems, barriers, and challenges in the development of industrial symbiosis. In response to these obstacles, managers implement a management system to ensure commitment to the sustainability-profitability compromise. It comprises a set of eco-industrial development values, principles, and processes.

EID’s core values and principles are based on a financial, social, environmental, and human bottom line. Financially speaking, it stipulates that industrial symbioses between organizations should be based on mutual success and greater investment autonomy. To promote a higher level of integration between industrial ecosystem components on a social level, it defends cultural awareness. Regarding environmental concerns, it is asserted that ecosystems are directly dependent on managers’ respect for biodiversity and consideration of the future effects of productive and commercial activities. It states that the quality of interactions between managers, employees, customers, suppliers, and government officials should be founded on transparency, dialogue, and respect.

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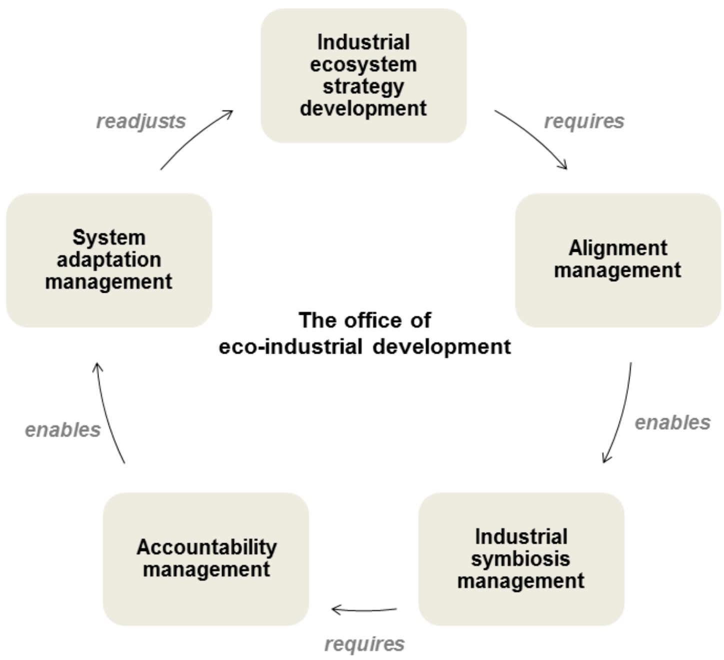
[50] The environmental movement of the last quarter of the 20th century led to the development of environmentally friendly social norms.

In operational terms, the EID process consists of five sequential key sub-processes leading to an industrial symbiosis commitment[51]: (i) industrial ecosystem strategy development; (ii) alignment management; (iii) industrial symbiosis management; (iv) accountability management; and (v) system adaptation management. As illustrated in Figure 10, these sub-processes are narrowly interrelated. Industrial ecosystem strategy development requires alignment management. Alignment management enables industrial symbiosis management. Industrial symbiosis management requires accountability management. Accountability management enables system adaptation management. System adaptation management readjusts industrial ecosystem strategy. All these five management processes are applied recursively to create an increasingly integrated community based on cooperation, interaction, efficiency, resources, and system thinking.

Figure 10 – The sub-processes of the management system towards eco-industrial development




Source: Adapted by the author from data analysis.

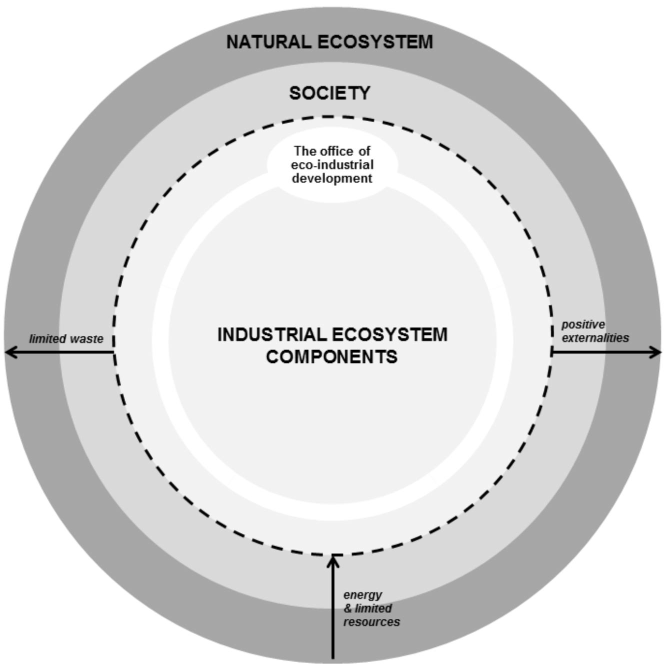
[51] The word "commitment" is used to show that the success of an eco-industrial development initiative depends on a voluntary, legally binding agreement between businesses.

## 5.2 The office of eco-industrial development

The case study of the Benevides Industrial Ecosystem and the eco-industrial development initiatives depicted by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010) provided evidence that an organization that works as an office of eco-industrial development conducts the management system that leads to an industrial symbiosis commitment.

Figure 11 shows that the OEID team clusters businesses by building awareness about industrial symbiosis and supporting the implementation of voluntary, legally binding agreements between companies. Most importantly, they support the constitution of a closed loop among firms analogous to the closed cycle of materials, nutrients, and energy in natural ecosystems. OEID staff leads the community of firms from linear material flows in "type I" ecology toward quasi-cyclic material flows in "type II" ecology. This type of system is characterized by a dependence on resources and energy from the external environment and a limited production of waste. Meanwhile, the ultimate goal of OEID is to lead industrial ecosystem components to perform cyclic material flows in "type III" ecology. This is a sustainable production chain with a great capacity for recycling.

Figure 11 – The role of the office of eco-industrial development



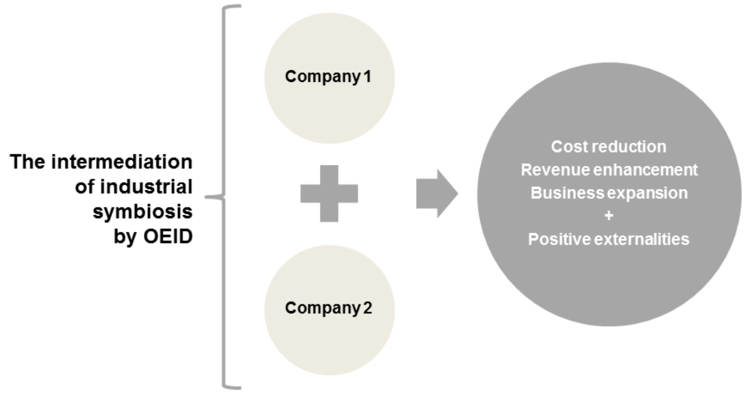

Source: Adapted by the author from data analysis.

The OEID team institutionalizes policies and practices that enhance the competitiveness of industrial ecosystem components while simultaneously advancing the economic, social, and environmental conditions in the communities in which they operate. It is a dynamic process of constant improvement that lays down new goals each year. Despite the fact that policies and operating practices are constantly being adapted, the values that influence the management system toward commitment to the sustainability-profitability trade-off are invariable. Direct communication, partnerships, open dialogue, sharing of knowledge, thinking about the future, being aware of cultural diversity, respecting biodiversity, and being committed to social changes that are good for the environment seem to be the best values for successful eco-industrial development.

Regarding the governance model adopted at the industrial ecosystem level, OEID serves as the primary manager and employs a persuasion-based management style. Its role is limited to the promotion, maintenance, and development of industrial symbioses, allowing industrial ecosystem components to determine their own participation in the trade of by-products, waste, and end-of-life products. By translating the principles, values, and processes of the management system towards commitment to EID into objectives, metrics, targets, initiatives, and budgets, a process that includes planning, implementation, evaluation, and adaptation, OEID fosters a business environment based on trust, openness to dialogue, and transparency. This approach facilitates the incorporation of business entities into an industrial ecosystem.

Since industrial symbioses are a fundamental mechanism for the trade-off between sustainability and profitability, the OEID team spends the majority of its time coordinating them. As depicted in Figure 12, OEID acts as a coordinating organization responsible for establishing mutually beneficial industrial symbioses.

Figure 12 – The intermediation of the industrial symbiosis agreement by OEID



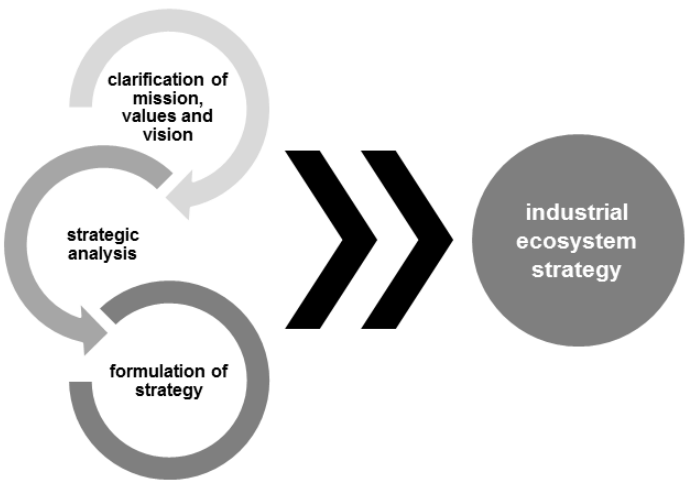

Source: Adapted by the author from data analysis.

The data analysis process indicated that OEID assumes the responsibilities of industrial symbiosis management for all industrial ecosystem components, not only to facilitate the trade of by-products, waste, and end-of-life products but also to ensure consistency over time. Therefore, the OEID team requires significant scientific, technological, and management capital, as well as financial resources, to develop industrial symbioses. They must generate positive externalities for society and natural ecosystems while achieving cost reduction, revenue growth, or business expansion.

### *5.2.1 Industrial ecosystem strategy development*

Industrial ecosystem strategy development refers to the articulation of industrial symbiosis, which specifies a comprehensive IS solution for achieving cost reduction, revenue enhancement, or business expansion as well as the generation of positive externalities for the surrounding community and natural ecosystems. As shown in Figure 13, the operational formulation of industrial symbiosis involves three fundamental activities: (i) clarification of mission, values, and vision; (ii) strategic analysis; and (iii) formulation of strategy. Clarification of mission, values, and vision is a prerequisite for strategic analysis, which guides the formulation of strategies.

Figure 13 – Industrial ecosystem strategy development by OEID




Source: Adapted by the author from data analysis.

Understanding the extent of the industrial ecosystem, mapping potential industrial symbiosis opportunities, identifying the points of intersection between the industrial ecosystem and the surrounding communities and natural ecosystems, and conducting risk analysis are all tasks of strategic analysis. Strategy formulation involves the tasks of articulating the value proposition and identifying the key industrial symbioses, CSR instruments, and strategic enablers.

Regarding the evaluation of industrial ecosystem extent, the evidence suggested that managers should consider the boundary of an industrial ecosystem to be nebulous and subject to change over time as a result of the entry and exit of business organizations. In addition, the boundary is open to its surroundings because industrial ecosystem components depend on the utilization of beliefs, practices, learned behaviors, and moral values from nearby and distant communities, as well as ecosystem services from the surrounding natural environment. In other words, adjacent communities and biological diversity interact closely and frequently depend on one another for the maintenance of ecosystem services that allow industrial ecosystems to function.

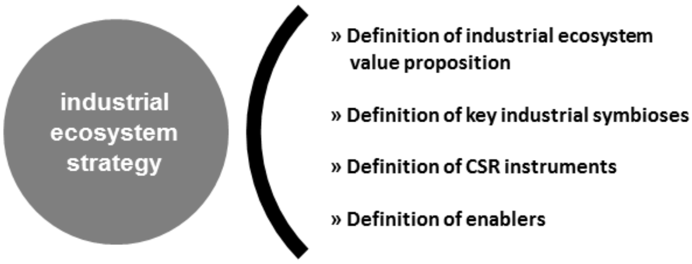
Society and the surrounding environment are, to some extent, secondary components of an industrial ecosystem. Their components generate economic opportunities, which makes them valuable assets to EID. Energy and resources provided by ecosystem services for manufacturing are processed by technology created by society, which simultaneously creates demand for products. The use of ecosystem services and cultural heritage by industrial ecosystem components should always include efforts to value and preserve them for future generations.

Opportunities for industrial symbiosis are mapped by identifying a trade of by-products, wastes, or end-of-life products involving at least three organizations, preferably according to a food chain (producer, consumer, and decomposer). Industrial symbiosis presents business organizations with opportunities for cost reduction, revenue enhancement, and business growth. Once IS opportunities have been designed to contribute to the creation of a healthy society and the preservation of the environment, the OEID management team should connect social and environmental issues from the surrounding communities and natural ecosystems with the trade of by-products, wastes, or end-of-life products. This analysis allows them to choose which social issues to address through the industrial ecosystem.

The collected data confirmed that addressing social issues is necessary, given that negative effects such as unemployment, social inequality, housing shortages, violence, environmental crimes, geographical isolation, and a lack of access to essential public services can disrupt business operations. These social and environmental costs may result in internal costs that render businesses unprofitable. Consequently, the incorporation of businesses into IS opportunities guarantees the expansion and integrity of business operations. Unfortunately, ineffective local government can have a negative impact on IS achievement, efficiency, and innovation. To combat this negative effect, managers should conduct a risk assessment and develop solutions.

Once the strategic analysis is done, the OEID team should come up with an industrial ecosystem strategy that encompasses four parts, as seen in Figure 14: the value proposition, key industrial symbioses, CSR instruments, and strategic enablers.

Figure 14 – The content of an industrial ecosystem strategy



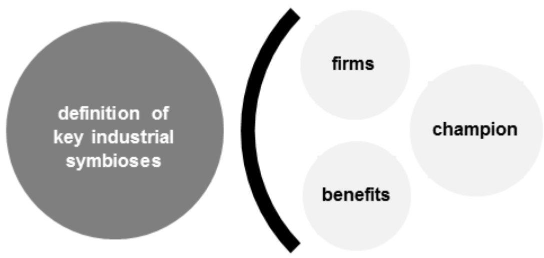

Source: Adapted by the author from data analysis.

The industrial ecosystem value proposition is narrowly related to the following objectives: to advance access to special raw materials; to ensure a reliable supply; to generate income for the families involved in the supply chain; to value by-products, wastes, and end-of-life products in monetary terms in order to encourage recycling; to build an environmentally friendly brand identity; to achieve a price premium; to attain manufacturing efficiency; and to preserve the symbiotic relationship between the industrial ecosystem, its members, and the surrounding area. For an industrial ecosystem to deliver on its promise of value, it needs key industrial symbioses, CSR instruments, and strategic enablers.

The definition of key industrial symbioses derives directly from the mapping of potential industrial symbiosis opportunities. OEID managers must consider how much waste and by-product each member of the industrial ecosystem generates when developing industrial symbioses. By imitating functional processes found in terrestrial ecosystems, such as primary productivity, decomposition, and trophic interactions, the OEID management team leads business organizations to perform a loop closure. This operational process is analogous to the closing cycle of materials, nutrients, and energy inherent to “type III” ecosystems. At the same time, the OEID team promotes more than the standard model of industrial symbiosis, which is limited to the exchange of by-products, wastes, and end-of-life products. In addition, industrial symbioses also involve the sharing of intangible assets, distribution channels, facilities, and contiguous processes. Thus, instead of being tied to by-products, wastes, and end-of-life products, industrial symbiosis becomes a mechanism for optimizing all resources available in the entire industrial ecosystem.

In addition to technical issues, the definition of key industrial symbioses includes a description of the companies chosen to take part in eco-industrial development and the potential benefits for the companies, society, and the environment (FIGURE 15).

Figure 15 – The content of the definition of key industrial symbioses




Source: Adapted by the author from data analysis.

Due to the complexity of industrial symbiosis and the high level of commitment required for the sustainability-profitability tradeoff, the evidence suggests that the OEID management team pre-selects companies for eco-industrial development. To engage in industrial symbioses, they choose businesses with exemplary social and environmental performance. Consequently, OEID always selects companies with the greatest capacity to conserve natural resources and generate positive social impact. In addition, OEID prioritizes organizations with sound corporate governance practices. As a result, newcomers must account to all stakeholders, not just shareholders.

The champion is one of the most important members of an industrial ecosystem. It is a crucial organization for eco-industrial development. In terms of function, the champion is the catalyst. Once it fosters the formation of a series of industrial symbioses around it to complement its core business, this exceptional company will precipitate EID. For this reason, to initiate eco-industrial development, the OEID management team must align key industrial symbioses with the business strategy of the champion.

By predicting the benefits derived from key industrial symbioses, OEID staff generates valuable information about its eco-industrial development project, thereby increasing its appeal to potential firms and partners. In light of the fact that industrial symbiosis agreements are typically entered into in pursuit of private benefits, the definition of prospective benefits facilitates the investment decisions of potential firms in eco-industrial development. Probably, the following private benefits encourage firms to invest in industrial symbiosis opportunities:

firms win customers' loyalty and keep them; firms get employees' commitment and better productivity at work; firms protect natural ecosystems and ensure the supply of energy and resources; firms reduce social problems and lower internal costs; firms gain skills that would be hard to get otherwise; firms get help from the government and NGOs.

This last private benefit is positively correlated with the definition of corporate social responsibility instruments in industrial ecosystem strategy. Despite their purely commercial purpose of exchanging by-products, wastes, and end-of-life products, industrial ecosystems must generate positive externalities[52] for society and natural ecosystems. CSR instruments enable industrial ecosystems to accomplish this objective, working to maintain a dynamic equilibrium for adjustment and regulation within industrial ecosystems. CSR instruments serve as a homeostatic response to a challenge[53] from the surrounding environment that tends to disrupt the normal state of an industrial symbiosis. According to the evidence, they are investments in society and natural ecosystems that support industrial ecosystem members' production efficiency. They are part of industrial ecosystem companies' economic growth, which is used to make sure the industrial symbioses continue to exist or grow.

CSR instruments are centered on the intersections between the industrial ecosystem and its surrounding social and environmental problems. Consequently, they address social problems in which the industrial ecosystem, local community, and environment are interdependent. In order to achieve homeostasis regulation, the OEID team should manage socioeconomic and environmental CSR instruments. Socioeconomic benefits are investments made in demographic, economic, sociopolitical, science and technology, cultural, and religious dimensions. The data collected suggests that they have an indirect impact on ecosystem services. Environmental benefits are investments in changes in local land use and cover, the introduction or eradication of species, adaptation and use of technology, external inputs, harvesting and resource consumption, climate change, and natural, physical, and biological drivers. They have a direct impact on natural ecosystems, as indicated by the evidence.

Implementation of key industrial symbiosis agreements and CSR instruments is contingent on the availability of a variety of enablers, including specific human capital capabilities, technological advancements, financial instruments, partners, and policy and regulatory frameworks.

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[52] Positive externalities mimic the notion of ecosystem goods and services.
[53] A "challenge" is a social or environmental problem that increases the internal costs of firms.

Figure 16 – The definition of enablers in industrial ecosystem strategy


Source: Adapted by the author from data analysis.

Figure 16 demonstrates that an eco-industrial development initiative's strategy requires the following: (i) human capital: managers, employees, customers, suppliers, and government officials capable of establishing interactions based on transparency, dialogue, respect, trust, and commitment to the sustainability-profitability trade-off; (ii) technology innovation: firms need advanced scientific knowledge to perform product and process innovation in order to take advantage of industrial symbiosis opportunities; (iii) financial incentives: a champion that generates economic stimuli, such as the price appreciation of by-products and wastes and co-branding[54]; (iv) collaborators: governmental agencies, nongovernmental organizations, and universities with in-depth understanding of the socioeconomic and environmental challenges and opportunities in the region where the industrial ecosystem operates; and (v) institutional change: the OEID management team should work with the government to develop policies and regulatory frameworks that promote eco-industrial development. In addition, for industrial ecosystem strategy to be effective, it requires alignment management.

### *5.2.2 Alignment management*

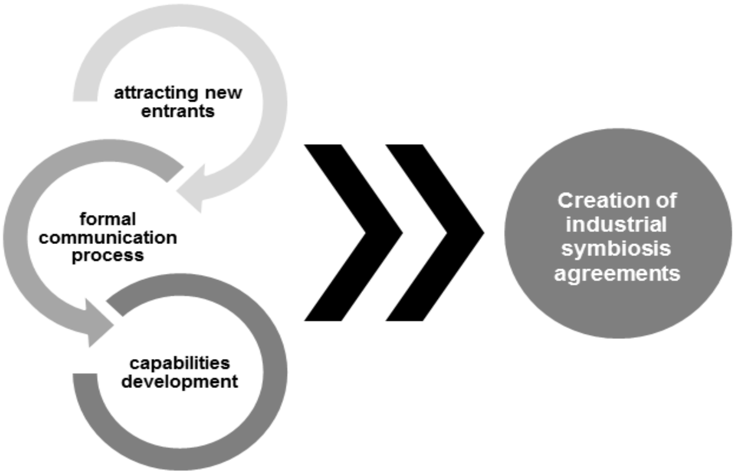
Alignment management aims to stimulate the creation of a series of industrial symbiosis agreements within a region according to an industrial ecosystem strategy. By means of this subprocess, the OEID team seeks to foster economic development while bringing positive externalities to the local community and the natural environment[55].

According to Figure 17, the three components of alignment management are attracting new entrants, a formal communication process, and capability development. These

[54] Co-branding is a form of sponsorship in which the champion lends its name to an industrial ecosystem in order to boost investments in industrial symbiosis opportunities.
[55] As the evidence suggests, bringing positive externalities into play is mandatory in the case of eco-industrial development.

procedures are deemed complete when businesses, NGOs, government agencies, labor unions, universities, and research institutions align with an industrial ecosystem strategy. Consequently, they are prepared for eco-industrial development.

Figure 17 – Alignment management by OEID




Source: Adapted by the author from data analysis.

To attract new entrants to an industrial ecosystem, OEID staff promote eco-industrial development and its function of establishing a profitable trade of by-products, wastes, and end-of-life products that are beneficial to society and natural ecosystems. Potential businesses, the champion, and partners outlined in the industrial ecosystem strategy are the campaign's primary target, which increases its effectiveness. During the campaign, OEID staff demonstrates to potential firms and partners that industrial symbiosis enables them to create more benefits for their customers or reduce total operating costs than they would be able to achieve by operating their waste management system independently.

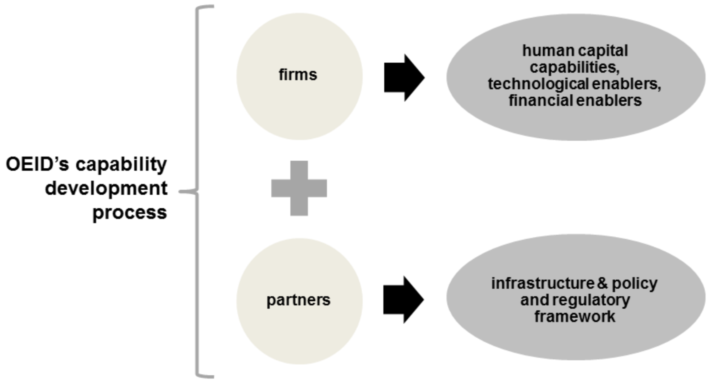
After the campaign, the OEID team engages in a formal process of communication with decision-makers from potential firms and partners interested in participating in its eco-industrial development project (FIGURE 18). The evidence indicates this procedure is intended to facilitate IS agreements. In doing so, OEID managers hold meetings and workshops to explain the industrial ecosystem strategy. The OEID team primarily demonstrates how to use key industrial symbioses to enhance shareholder value, increase stakeholder satisfaction, achieve economies of scale or value-chain integration, and develop and share intangible assets. In addition, decision makers recognize the importance of CSR instruments associated with key industrial symbioses for mitigating social and environmental issues that can increase the internal costs of their operations. Consequently, it is anticipated that decision-makers will initiate contact with one another to discuss industrial symbiosis agreements.

Figure 18 – Formal communication process by OEID


Source: Adapted by the author from data analysis.

OEID is the "driver" for eco-industrial development once voluntary agreement between decision-makers has been reached. Its staff assists new entrants in implementing the industrial symbioses in which they are involved through training, consulting, IT services, and financial assistance[56]. This is a capability development process that contributes to the development of the intangible assets required for IS operations by industrial ecosystem firms (FIGURE 19). OEID also urges partners to build the infrastructure, policies, and regulatory frameworks needed to support the major industrial symbioses.

Figure 19 – Capability development process by OEID




Source: Adapted by the author from data analysis.

According to evidence, by interacting with businesses and partners during the capability development process, OEID staff promotes their harmonious integration into an industrial ecosystem and, meanwhile, actively fosters a business environment based on trust, transparency, and dialogue. In addition, it stimulates industrial ecosystem firms' commitment to the sustainability-profitability trade-off, which contributes to the formation of long-lasting

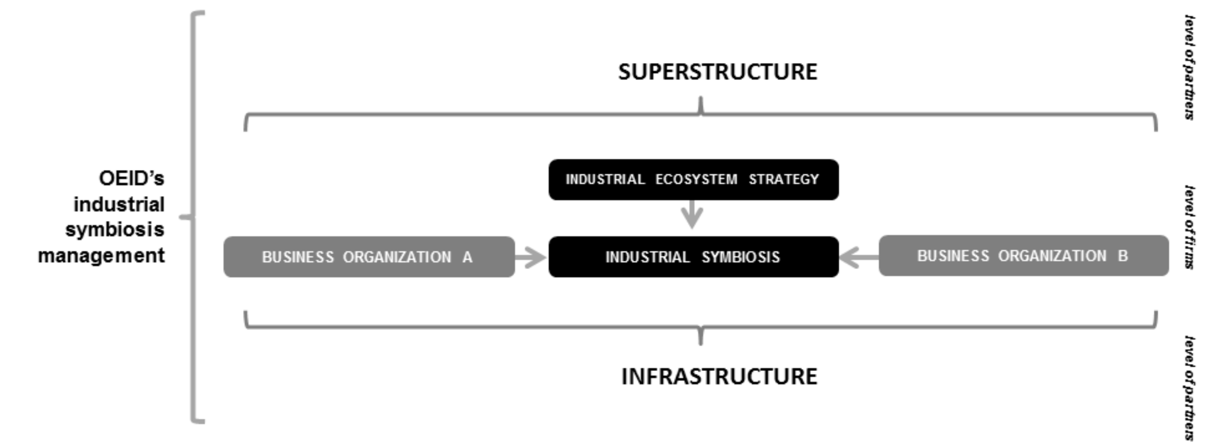
[56] Some cases demonstrate that the office of eco-industrial development charges for its services in capability development.

industrial symbioses. Importantly, OEID's alignment management process contributes to the diffusion of knowledge on the trade of by-products, wastes, and end-of-life products. Consequently, alignment management enables industrial symbiosis management.

### *5.2.3 Industrial symbiosis management*

Using industrial symbiosis management, the OEID team assists businesses in implementing the IS agreement. As shown in Figure 20, IS management is conducted on two levels: the level of partners and the level of firms. In accordance with the industrial ecosystem strategy, the OEID team promotes the development of enablers that support IS agreements at the partner level[57] in order to help industrial ecosystem firms achieve their objectives. With the aim of facilitating bindings at the firm level, the OEID team provides on-site technical consulting. The purpose of on-site technical consulting is to train industrial ecosystem firms' managers and employees on how to conduct a six-step method for successful industrial symbiosis development.

Figure 20 – Industrial symbiosis management by OEID



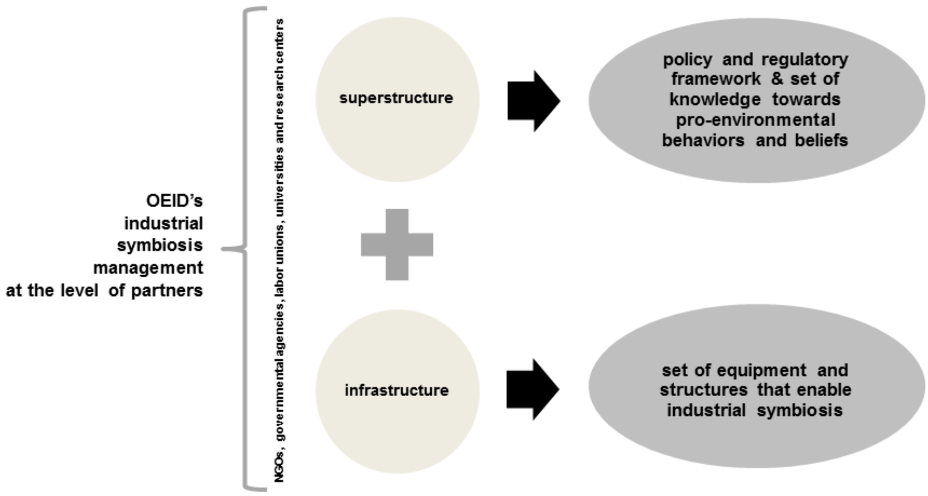

Source: Adapted by the author from data analysis.

As depicted in Figure 21, the OEID team collaborates directly with non-governmental organizations, government agencies, labor unions, universities, and research institutions from a region to construct the infrastructure and superstructure that support IS development. The political, philosophical, religious, moral, and cultural framework that organizes the trade of by-products, wastes, and end-of-life products within an industrial system is known as the superstructure. In this

[57] It is made up of nongovernmental organizations, government agencies, labor unions, universities, and research centers from a certain region.

instance, it includes the policy and regulatory framework as well as the body of knowledge that contributes to the formation of pro-environmental behaviors and beliefs that put industrial symbiosis into order. Infrastructure consists of the tools, machines, software, financial resources, and a set of techniques, processes, and methods that enable industrial symbiosis. It consists of eco-friendly technologies and financial aid, such as a credit line.

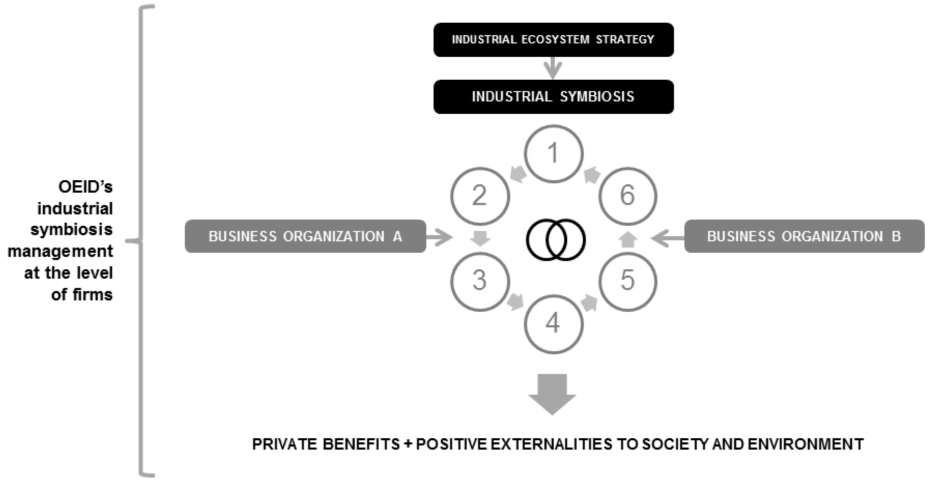
Figure 21 – Industrial symbiosis management at the level of partners




Source: Adapted by the author from data analysis.

The data suggests that managers of firms within an industrial ecosystem must view themselves as business partners that share ownership as well as responsibility for managing the industrial symbiosis and the income or losses it generates. As depicted in Figure 22 on the following page, to foster industrial symbiosis partnerships, the OEID team employs on-site technical consulting to teach managers of industrial ecosystem firms a six-step method for developing successful industrial symbioses.

Figure 22 – Industrial symbiosis management at the level of firms




Source: Adapted by the author from data analysis.

By utilizing that six-step method, the managers of industrial ecosystem firms can: (i) collaborate to develop an industrial symbiosis strategy; (ii) plan its measures, targets, and funding; (iii) align their employees; (iv) plan IS operations; (v) monitor the execution of industrial symbiosis; and (vi) adapt the industrial symbiosis strategy as needed. For the method's application to work, the OEID team has to go to each company that is part of an eco-industrial development project and provide professional help and advice.

Companies are responsible for planning and implementing industrial symbioses, despite the fact that OEID provides assistance. There is some evidence that they develop and plan their IS strategy, align their employees, plan IS operations, monitor the implementation of IS, and adapt their IS strategy as necessary. It is also important to point out that the industrial symbiosis implemented extends beyond the exchange of by-products, wastes, and end-of-life products. Firms can improve their social and environmental performance by creating financial, stakeholder, process, and knowledge symbioses.

To successfully implement an IS binding agreement, the managers of firms within the industrial ecosystem must first agree on an industrial symbiosis strategy and then devise metrics to measure how well that IS strategy is being implemented. They must communicate a shared vision and provide incentives to motivate employees to improve industrial symbiosis performance. Also, they need a process that lets them talk about problems openly, solve conflicts, share information, and keep adjusting the IS strategy to new internal capabilities and changes in the outside world.

Industrial symbiosis agreements should take into account the by-product and waste production limits of each company in order to establish long-lasting, profitable business partnerships. Firms' decision-makers should estimate the demand for by-products and waste on a horizon of "x" years to minimize the impact of market fluctuations on an IS agreement over time. During this period, they may adjust the volume of supply once every 12 months in response to fluctuations in market demand. However, they should guarantee the purchase of a minimum amount of the agreed-upon by-product and waste. Additionally, managers should not demand supply exclusivity, allowing their partners to negotiate surpluses with other companies. The prices for by-products and waste are always negotiated directly between business partners, without the involvement of a third party. The prices should adequately compensate their cost structure and allow them to attain cost reduction, revenue growth, or business expansion. In addition, costs should include all CSR instrument expenses.

### *5.2.4 Accountability management*

In the execution of industrial symbioses, accountability management is the process of monitoring and learning through metrics about problems, barriers, and challenges. OEID monitors the implementation of IS agreements over IS execution. This approach also allows OEID staff to identify the unique characteristics and requirements of each member of the industrial ecosystem, including local communities and natural ecosystems. To facilitate accountability management, OEID ought to mandate the traceability of all industrial symbioses in order to ensure their monitoring. There is evidence that data collection on IS execution is the responsibility of firms within an industrial ecosystem, which is confirmed by an audit of OEID. This procedure for managing accountability enables system adaptation management.

### *5.2.5 System adaptation management*

System adaptation management is the process of using data from industrial symbiosis execution and new external environmental data to test and adapt the industrial ecosystem strategy. Evidence shows the aim is to launch another loop toward eco-industrial development. This method is comparable to the resilience of natural ecosystems. Consequently, OEID's management of eco-industrial development is a dynamic, ever-improving process that establishes new objectives annually.

# 6 CONCLUSION

The goal of this study was to create a theoretical framework for the management of eco-industrial development (MEID). A process of building theory using a single case study was undertaken to accomplish this goal. The framework formulation was comprised of three broad stages. To begin, the researcher identified a priori concepts from the literature that were relevant for measuring constructs and confirming construct relationships. Secondly, a case was chosen for theoretical reasons. It was chosen to provide examples of industrial ecosystem management and to fill in a priori categories and subcategories. Lastly, the researcher looked at other research done between 2007 and 2012 and compared it to the preliminary theoretical framework.

The formulated framework identifies, conceptualizes, and connects MEID to other categories and subcategories in a systematic manner. It introduces a novel concept to the field of industrial ecology based on the coding of a dataset generated by a case study on the Benevides Industrial Ecosystem, which was conducted to gather evidence of the EID management process. MEID's generalization is based on its similarity to industrial ecosystem management approaches employed by well-known eco-industrial development initiatives, such as those demonstrated by Atitude (2011), Behera *et al*. (2012), Boons, Spekkink, and Mouzakitis (2011), Chertow and Ehrenfeld (2012), Paquin and Howard-Grenville (2012), Pellegatti (2007), Sakr *et al*. (2011), and Yuan *et al*. (2010).

Industrial ecology (IE) lacks a management approach for the industrial ecosystem due to its emphasis on a techno-environmental approach based on a mechanistic viewpoint of the industrial ecosystem. This gap is filled by the suggested framework, which explains how to incorporate eco-industrial development concepts into the corporate-level strategies of business organizations within an industrial ecosystem. In doing so, the developed model describes a process for managing industrial ecosystems that puts EID ideas into action.

Specifically, the framework describes how the EID evolves over time in response to context changes, following five sub-processes: (I) industrial ecosystem strategy development; (II) alignment management; (III) industrial symbiosis management; (IV) accountability management; and (V) system adaptation management. As discussed, the office of eco-industrial development is responsible for putting these five sub-processes into practice. These sub-processes that the OEID team executes are part of a strategic management process. OEID performs this series of actions in order to generate private benefits for firms within an industrial ecosystem while intentionally generating positive externalities.

The developed framework is derived from interviews with managers, during which they provided lay discourse, and it is hoped that the theoretical statements expressed in this thesis will become a part of that discourse, thereby irreversibly altering it. They bring the knowledge that it can be appropriated by managers themselves and subsequently reapplied as part of their discourse and management approach. Accordingly, the formulated framework is likely to have practical consequences for eco-industrial development.

**The effectiveness of the methodology.** Bringing a management process for eco-industrial development to the field of industrial ecology was an essential part of the framework's formulation. The process of elaborating the framework presented has involved writing about processes that have not yet been named, conceptually developed, or linked to other concepts in a systematic way within a theoretical framework.

The framework formulation was the main goal around which the eight stages of the current research were organized. In general, they entailed first observing the actions of managing a real industrial ecosystem to see how and why management of eco-industrial development evolves in response to changes in external conditions, and then comparing preliminary findings with similar empirical studies.

The "how" and "why" questions regarding the MEID were answered using a qualitative approach. The case study research method was chosen because it is more effective at investigating the MEID as it manifests itself to the researcher. In terms of the application of the case study, the researcher validated several a priori concepts and their relationships inherent to EID, going beyond a descriptive study. In order to provide MEID guidelines, the case study required not only the construction of concepts but also their integration into a logical scheme.

Axioms, theorems, or propositions about EID were not taken into consideration by the researcher to preserve theoretical flexibility. However, the researcher has chosen 59 a priori constructs from the literature to provide a stronger foundation for the construct measures. In this way, they were distributed into six macro variables: (I) the office of eco-industrial development; (II) the development of an industrial ecosystem strategy; (III) alignment management; (IV) industrial symbiosis management; (V) accountability management; and (VI) system adaptation management.

The researcher focused their efforts on a theoretically useful case: an industrial ecosystem supported by Natura Cosméticos S.A., the second-ranked company on the 2012 Global 100 List whose products are derived from biodiversity. This industrial ecosystem is distinguished by its proximity to suppliers of natural essences in the Amazon Rainforest in the northern region of Brazil.

In order to strengthen the grounding of the theoretical framework by triangulating evidence, multiple data gathering techniques were employed: semi-structured interviews with Natura's managers and suppliers; document gathering including text, videos, and pictures; and non-participant observation. To increase the rigor and trustworthiness of the findings from qualitative data, the researcher applied a triangulation of data analysis. Therefore, more than one type of data analysis technique was used to understand the phenomenon of the management of EID in the industrial ecosystem fostered by Natura in Benevides, Pará.

During the initial phase of data analysis, open coding and axial coding were utilized to establish a preliminary theoretical framework. These techniques allowed for the constructs' definition, validity, and measurability. The researcher then employed selective coding to search for evidence of relationships between constructs, which contributed to the internal validity of the emerging framework. He finally compared the preliminary theoretical framework with similar literature published between 2007 and 2012 regarding industrial symbiosis and eco-industrial development. This method of data analysis enhanced internal validity, raised the level of theory, and improved construct definitions and generalizations.

**Research limitations.** Standard procedures for theory building require the integration of qualitative and quantitative sampling, data collection, and analysis methods (EISENHARDT, 1989). Due to time and resource constraints, the researcher collected and analyzed only qualitative data. Although semi-structured interviews with Natura's managers and suppliers, document gathering, and non-participant observation were extremely enlightening for the current study, objective measurements could have enriched the data collected. Incorporating both qualitative and quantitative methods into this study may have been the optimal strategy. The framework would be strengthened as a result of the triangulation made possible by mixed-methods research. However, multiple techniques for sampling, data collection, and analysis would have been labor-intensive and required more time and resources than were available to the researcher at the time of the study.

To strengthen the foundation of the formulated framework, the present study should have included the following: (i) the collection and analysis of both quantitative and qualitative data; (ii) detailed procedures for collecting and analyzing data that are well-suited to each research strategy; (iii) the right sample size for both quantitative and qualitative analysis; (iv) the integration of data during data collection, analysis, or discussion; and (v) the use of qualitative and quantitative procedures at the same time or in a different order, with the same sample or a different sample.

Quantitative and qualitative data collection and analysis would have provided a proper perspective on the evidence in the current study. Quantitative data could have assisted the researcher in recognizing relationships that were not readily apparent. In addition, it could have avoided qualitative data that led the researcher to erroneous conclusions. If included, objective measurements would have supported and strengthened the non-numerical evidence. It would also have provided a theoretical framework that could have been supported by numerical evidence. Comparatively, qualitative data would have helped the researcher understand the causal relationships underlying the categorical data.

**Recommendations for future research.** For the purpose of advancing the formulated theoretical framework, researchers should study additional cases. New initiatives of eco-industrial development might fill the categories and subcategories expounded in the present study. It makes sense to select extreme cases where the EID process is clearly visible.

In addition to conducting multiple case studies to explore the management of eco-industrial development, researchers may use three data analysis techniques suggested by Eisenhardt (1989): (i) a cross-case analysis to see evidence beyond the formulated theoretical framework; (ii) checking if construct relationships presented fit with the evidence in each new case to confirm, extend, and sharpen the proposed framework; and (iii) comparing the theoretical framework presented with conflicting literature to establish internal validity, raise the theoretical level, and sharpen the construct definitions.

A cross-case analysis may overcome the poor information processing that hampered the current framework's construction. The researcher might have rushed to conclusions based on inadequate data, been excessively swayed by chatty or more elite respondents, accidentally eliminated conflict evidence, or overlooked theoretical saturation. As a consequence of these information-processing biases, the researcher may have arrived at a premature theoretical framework. A cross-case comparison might be able to get rid of these biases by looking at the framework presented from different points of view.

When doing a cross-case analysis, researchers might choose constructs indicated by the proposed framework and then search for similarities and differences within the set of cases. A helpful strategy is to compare Natura's case with fresh ones and then attempt to uncover construct similarities and differences between each pair. This approach necessitates researchers making careful observations. The search for distinctions in situations that seem to be similar to Natura may refresh the theoretical framework presented. Similarly, looking for similar characteristics between obviously different instances and BIE might lead to a more in-depth understanding. These comparisons could lead to new ideas and connections that the existing theoretical framework did not account for.

A cross-case analysis may motivate researchers to go beyond the theoretical framework presented, particularly when comparing Natura's case to new ones. This strategy increases the possibility of a tight match between the proposed framework and the empirical context. Cross-case analysis also makes it more likely that researchers will find new information that the author of this thesis did not know about before.

Following a cross-case analysis, new impressions, themes, ideas, and potentially even connections between constructs may emerge. It is strongly advised that the framework presented be rigorously compared to the data from each new case. Researchers must regularly examine how effectively or poorly the framework formulated in this study matches new facts. Eisenhardt (1989) says that a close match is important because it leads to a theory that can be tested.

The next step in the advancement of the existing theoretical framework could be an examination of the correspondence between the presented construct relationships and data from various cases. Researchers can look into whether new cases confirm, amend, refute, or build on the theoretical statements presented, or whether they should be ignored due to a lack of evidence. Cases that corroborate theoretical statements increase trust in the relationships' validity. Cases that contradict theoretical statements may provide an opportunity to improve and enhance the current theoretical framework. As a result, each case may help validate or refute the formulated construct relationships.

Examining literature that contradicts the existing theoretical framework is another technique to further the current study. This method may allow researchers to testify that the constructs and their relationships are wrong (a challenge to internal validity) or are not shared by other instances (a challenge to generalization). Perhaps more crucially, contradictory literature may encourage researchers to think more imaginatively than the author of this thesis could otherwise. Finally, researchers may get a better understanding of the theoretical framework presented as well as the limitations of the present research's generalization.

**Research contributions.** The theoretical framework for the management of eco-industrial development (MEID) can contribute to translating the theories of industrial ecology into practice. It substantially relies on industrial symbiosis to reduce industrial systems' impact on the natural environment. Accordingly, business managers now have information explaining how to transform industrial systems into closed-loop systems where by-products, wastes, and end-of-life products can become inputs for new processes. As a result, managers will be able to foster the process of eco-industrial development, the creation of win-win relationships between business organizations and local communities, and the improvement of economic, social, and environmental indicators.

The presented theoretical framework attempts to materialize the traditional normative goal of the field of industrial ecology, which establishes type III ecosystems as the paradigm of efficient cycling of resources. It was built to enable managers to design industrial ecosystems that mimic the closed-loop properties of type III ecosystems and promote dynamic and harmonious relations with the biosphere. The strong emphasis in the presented framework on the building of closed ecological systems is heavily influenced by a classic study conducted by Graedel and Allenby (1995). The authors observed that type III ecosystems have the greatest degree of cycling and the least reliance on external resources and sinks. Thus, they were seen as a model for how to design industrial ecosystems of many different sizes.

Business managers may follow the presented framework to carry out an eco-industrial development program. It includes the initiation, planning, execution, and monitoring of industrial symbiosis between business organizations involved directly or indirectly in the same value chain and located in the same geographical space. Such integration requires companies to share information and processes with each other while revaluing their by-products, wastes, and end-of-life products as resources.

The present study puts forward a collection of interrelated theoretical statements, which are summarized as follows: (i) The entire eco-industrial development process culminates in the formation of an industrial ecosystem, which is an economic system that sustains local communities and natural ecosystems through the trade of by-products, wastes, and end-of-life products; (ii) For its maintenance, an industrial ecosystem needs the organization responsible for EID to address social or environmental issues in its surrounding area that may disrupt the normal state of industrial symbioses; (iii) The solutions to external threats consist of investments made in socioeconomic and environmental factors that support industrial symbioses; (iv) Money for the chosen social and environmental causes comes from the part of economic growth generated by industrial symbioses.

These are assertions about EID that transform an industrial ecosystem into a model for an environmentally friendly business network that offers the means to demonstrate how businesses can be not only profitable but also ethical and responsible members of society. This concept of the industrial ecosystem may be regarded as an advancement in waste management.

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## APPENDIX A – DATA COLLECTION LETTER

Dear Xxxxx[58],

Under the academic supervision of Professor Raymond Côté at Dalhousie University's School for Resource and Environmental Studies (SRES), I developed an analytical framework for the management of industrial ecosystems to assess the degree of eco-industrial development. My aim is to test such an analytical framework through a questionnaire at Natura's facility in Benevides, Pará. This questionnaire seeks to examine a list of administrative procedures for eco-industrial development distributed along five key processes: (1) Industrial ecosystem strategy; (2) alignment management; (3) industrial symbiosis management; (4) accountability management; and (5) system adaptation management.

The success of my research depends on the participation of managers and suppliers who are directly or indirectly linked to the industrial ecosystem designed by Natura in Benevides, Pará. Please be advised that each respondent will not need to commit more than 15 minutes to doing so. The research work, after completion, will be used to diagnose potential problems and identify the organization's progress in relation to eco-industrial development.

We stress that the information contained in the questionnaires will be handled exclusively by the research team and that there will not be any kind of information on work that enables the identification of those who answered the questionnaire, maintaining the confidentiality of responses.

Thanks in advance for your cooperation, and I look forward to receiving your approval.

Best regards,

**Leonardo de Queiroz Braga Cavalcante**
Master's Student at Graduate Program in Administration and Controllership
Faculty of Economics, Administration, Actuarial Science, and Accounting
Federal University of Ceara

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[58] ***Xxxxx*** alludes to the name of BIU general manager that was hidden to protect his personal identification.

# APPENDIX B – SEMI-STRUCTURED INTERVIEW GUIDE

**Semi-structured interview guide**

**Introduction**

I created a framework for the management of eco-industrial development. Now I need to validate this framework through a case study of the Benevides Industrial Ecosystem.

The goal of the case study is to find out more about five processes to manage eco-industrial development: (1) coming up with an industrial ecosystem strategy; (2) managing alignment; (3) managing industrial symbiosis; (4) managing accountability; and (5) managing system adaptation.

To do so, managers and suppliers that deal with the Benevides Industrial Ecosystem in some way must respond to a series of questions. This will take no longer than sixty minutes of your time.

I want you to know that your responses are anonymous and that no one will use the information I collect to determine who answered to the questions.

When the research is done, you will be able to use the framework to undertake eco-industrial development initiatives.

Thanks in advance for your cooperation.

| Questions | Topics |
|---|---|
| “Tell me what you think about…”<br>“What happens when…?”<br>“What your experience with…?” | 1. Industrial ecosystem<br>2. Industrial ecosystem strategy<br>3. Alignment<br>4. Industrial symbiosis<br>5. Accountability management<br>6. System adaptation management<br>7. Industrial ecosystem’s benefits |

# APPENDIX C – CODING SUMMARY BY SOURCE

The summary of coding by source generated by NVivo is displayed in Table 34. Briefly, it shows the total number of references (sentences) extracted from internal and external sources (documents, interview transcripts, and literature) that were assigned to nodes. These are the categories and subcategories that represent the defining characteristics of BIE, the subprocesses and supporting activities of the management of eco-industrial development, and their relationship statements. In the "Number of Text References" column, the total number of coded content from each source is indicated. The total number of references was calculated based on coding done by the researcher. Each cell in the column refers to the coded sentences for multiple nodes. In the "Number of Nodes Coding Source" column, the number of nodes created by the researcher after exploring and coding the source is revealed. Each column cell indicates multiple nodes established through coding. In the column labeled "Coded Percentage of Source," the coverage percentage denotes what proportion of the source content was coded at the multiple nodes. The calculation method for coding coverage is based on the mean of (i) the percentage of characters coded (as text selections) at the nodes and (ii) the percentage of the page area coded (as region selections) at the nodes.

Table 34 – Coding summary by source

| Source | Total Words in Source | Total Paragraphs in Source | Number of Text References | Number of Nodes Coding Source | Coded Percentage of Source |
|---|---|---|---|---|---|
| Natura Document 01 | 6795 | 376 | 457 | 73 | 0.7147 |
| Natura Document 02 | 3293 | 255 | 129 | 36 | 0.3880 |
| Natura Document 03 | 4987 | 291 | 127 | 19 | 0.5815 |
| Natura Document 04 | 2622 | 312 | 102 | 30 | 0.3110 |
| Interview transcript 01 | 7635 | 335 | 459 | 53 | 0.5784 |
| Interview transcript 02 | 6001 | 117 | 1008 | 65 | 0.8582 |
| Interview transcript 03 | 3957 | 90 | 790 | 59 | 0.9459 |
| Interview transcript 04 | 4806 | 80 | 1036 | 54 | 0.9143 |
| Interview transcript 05 | 1777 | 51 | 331 | 34 | 0.8525 |
| Interview transcript 06 | 4210 | 61 | 733 | 58 | 0.8811 |
| Interview transcript 07 | 2245 | 53 | 383 | 44 | 0.7684 |
| Interview transcript 08 | 4152 | 94 | 567 | 41 | 0.8884 |
| Interview transcript 09 | 3718 | 82 | 397 | 42 | 0.6782 |
| Interview transcript 10 | 1751 | 53 | 547 | 43 | 0.7019 |
| 2007 – Pellegatti | 8175 | 200 | 946 | 29 | 0.3690 |
| 2009 – Yuan *et al*. | 5502 | 173 | 112 | 11 | 0.2617 |
| 2011 – Atitude | 7004 | 128 | 243 | 19 | 0.3101 |
| 2011 – Boons, Spekkink and Mouzakitis | 7653 | 170 | 126 | 14 | 0.1138 |
| 2011 – Sakr, El-Haggar and Huisingh | 10364 | 328 | 340 | 22 | 0.1855 |
| 2012 – Behera *et al*. | 8957 | 263 | 391 | 24 | 0.2455 |
| 2012 – Chertow and Ehrenfeld | 11192 | 299 | 356 | 15 | 0.1912 |
| 2012 – Paquin and Howard-Grenville | 8600 | 252 | 164 | 9 | 0.2318 |

Source: Adapted by the author from NVivo 10.