Sustainable Value Generation through Collaborative Symbiotic Networks Planning

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Abstract

Industrial Symbiosis is an important component of Industrial Ecology which studies the collaboration and coexistence of companies to achieve mutual benefits. Its concepts have traditionally focused on eco-efficiency and its direct benefits such as costs reduction, resources optimization and environmental impacts reduction. The paper introduces the use of externalities and sustainable value concepts as tools to amplify the spectrum of opportunities and, consequently, the potential value of Industrial Symbiosis development. Externalities are related to side effects of companies' decisions and acts. They offer a broader systemic view to Industrial Symbiosis planning and execution. Sustainable value brings up intangible value drivers such as institutional, organizational and relationship capital as well as risk management consideration. It helps companies to visualize the totality of potential value of Industrial Symbiosis

Keywords: Industrial Symbiosis; Externalities;Value Generation;

Introduction

Industrial symbiosis concept has originated from industrial ecology in allusion to the mutualism between living beings, and it has been studied by academics with great impulse since the 1990s. It is an important form of collaboration between companies when considering that the value created by them becomes greater than the sum of the eventual value created by each one individually. Industrial symbiosis traditionally offers three types of opportunities: infrastructure sharing, services sharing and reuse of energy and materials (water and co-products). Their benefits include primarily economies of scale from physical assets, prevention of negative externalities and promotion of positive ones.

Externality denomination was pointed for the first time by economists, and refers to the positive or negative effects of a business decision over those who do not take part in it. It is constructive to apply the externality approach into the searching for symbiotic opportunities between industries or service companies, as it can enhance the potential for generating positive impacts over a larger group of stakeholders. Externalities control and symbiotic processes can influence positively the geographical region and its communities, since it attempts to compromise with the main negative and positive business side-effects.

The goal of this paper is to show the benefits of using the externality approach for the development of symbiotic collaborative networks. The collaboration between partners from the symbiotic network is able to generate value to a more diverse public.

If analyzed from a business perspective, externalities control can minimize risks, maximize eco-efficiency, reduce costs, generate revenue and increase institutional, organizational, relationship and intellectual capital. Therefore, addressing negative externalities and fostering positive externalities can significantly increase the potential value of industrial symbiosis.

Industrial Ecology: Concepts and Evolution

The study of industrial systems that operate more like natural ecosystems is known as Industrial Ecology (IE) [1]. The term was coined in the early 1990s, but the current concepts involved have been around for decades. They involve the sustainable philosophies of Reduce, Reuse, Recycle applied toward industry. It is based on environmental awareness and good economic sense.

Industrial Ecology has numerous aspects including pollution prevention, product life cycles, design for environment and green accounting [2]. A key concept is that processes and industries are seen as interacting systems rather than comprising isolated components in a system of linear flows. This provides a basis for thinking about ways to connect different waste-producing processes, plants or industries into an operating web that minimizes the total amount of industrial material that goes to disposal sinks or is lost in intermediate processes. The focus changes from minimizing waste from a particular process or facility (i.e. pollution prevention), to minimizing waste produced by the larger system as a whole, as well as reducing materials inflow [3, 4].

Industrial Ecology has the potential to improve the sustainability of manufacturing. The commercial viability is heightened by the recovery and use of waste and reprocessed materials as resources for a range of manufacturing processes. It works best where there is a strong agglomeration or clustering of firms that have the capacity to utilize waste as a resource in production. Proximity generates externality savings and of scale, which reduces operational costs for companies sharing common suppliers or services. It also encourages innovation, which leads to opportunities for the development of new industries— especially firms capable of using wastes and by-products. The more intense the agglomeration, the greater are the prospects for innovation and synergies [5].

Since the introduction of Industrial Ecology, the Industrial Symbiosis (IS) concept has been put in a new perspective.

Chertow [2], defines the concept of Industrial Symbiosis as "(…) part of the emerging field of Industrial Ecology, demanding resolute attention to the flow of materials and energy through local and regional economies. Industrial Symbiosis engages traditionally separate industries in collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity".

Based on the principles of Industrial Ecology and Industrial Symbiosis, a new concept has been developed. An Eco-Industrial Park, or EIP, is a public/private partnership where the Industrial Ecology and Industrial Symbiosis approach to industry is contained in one development. The benefit of this arrangement is that the waste material or product of one company can be recycled into the manufacturing process of one or more companies with minimal transportation and production costs. EIPs are designed to produce minimal emissions, minimal noise and ground pollution, and minimal waste. EIP firms are designed to fit the environment instead of adjusting the environment to fit the firm [6].

Industrial Symbiosis and Eco-Industrial Parks

The expression “symbiosis” builds on the notion of biological symbiotic relationships in nature, in which at least two otherwise unrelated species exchange materials, energy, or information in a mutually beneficial manner—the specific type of symbiosis known as mutualism [2]. A mutualism relationship refers to an association between two or more living beings where the benefits are greater than the sum of those reached by each of them separately. Therefore, Industrial Symbiosis means the association of two or more companies in order to achieve a greater value than the sum of value that they could achieve separately.

There are three primary opportunities for resource exchange: 1) By-product reuse - the exchange of firm-specific materials between two or more parties for use as substitutes for commercial products or raw materials. The materials exchange component has also been referred to as a by-product exchange, by-product synergy, or waste exchange and may also be referred to as an industrial recycling network. 2) Utility/infrastructure sharing - the pooled use and management of commonly used resources such as energy, water, and wastewater. 3) Joint provision of services - meeting common needs across firms for ancillary activities such as fire suppression, transportation, and food provision [7]

These resource exchanges are aimed to avoid disturbing the environment where the companies are located. Relocating the resources reduces the impacts since landfills, pollution and residues are reduced as well as natural resources necessity is reduced due to re-use. These are important tasks in Industrial Ecology and the limit of its development is known as Circular Corporation. According to Yang & Feng “Circular economy is an abbreviation of ‘Closed Materials Cycle Economy or Resources Circulated Economy’, aiming at the efficient use of resources, taking reducing, reusing and recycling as principles and ‘closed materials cycles and recycled use of energy’ as features” [8].

Another relevant point to understand Industrial Symbiosis is to know the usual elements and tools involved in its development. Chertow [7] summarizes them in five elements: embedded energy and materials, a life cycle perspective, cascading, loop closing, and tracking material flows; and four useful tools: industrial inventories, input/output matching, stakeholder processes and materials budgeting. Basically, the elements are focused on understanding and redesigning the flow of materials, water and energy while the tolls adds the important tasks of looking to present industries of the location and stakeholder engagement process.

Finally, the spatial aspect is also very important to Industrial Symbiosis development. When you think about reuse and exchange of materials, energy and water between different processes, or if you think about sharing of infrastructure and services, it is almost automatic to imagine it all physically located. Industrial Symbiosis does not have to necessarily happen between companies that are close to each other, but it increases possibilities. Chertow [2] divides material exchanges into 5 types, according to “where” they happen: “Waste exchanges (type 1); within a facility, firm, or organization (type 2); among firms placed in a defined eco-industrial park (type 3); among local firms that are not placed (type 4); and among firms organized ‘‘virtually’’ across a broader region (type 5)”. It is shown that exchanges could happen even virtually but it is makes also clear the importance of distances in opportunities in Industrial Symbiosis.

Since Industrial Symbiosis has spatial aspects as critical, its concepts are especially useful to industrial parks and its collocated firms. The term “Eco-Industrial Park” or EIP refers to an industrial park where companies are engaged into exchanging and sharing anything with partners at the park in a mutual benefit way. EIP are closely connected to Industrial Symbiosis concepts a study, and a very known definition was given by Cote [9], “(…) an eco-industrial park is an industrial system which conserves natural and economic resources; reduces production, material, energy, insurance and treatments costs and liabilities; improves operating efficiency, quality, worker health and public image; and provides opportunities for income generation from use and sale of wasted materials.”

Technical reports [10,11] on Eco-Industrial Park show that they differ a lot depending on geographical location, participant companies, government involvement and motivation for establishing it. Independently of how Eco-Industrial Parks are initiated or developed, they have the potential to bring several benefits to communities, environment and business. Some of them are listed in Table 1.

Table 1. *Potential benefits from Eco-Industrial Parks [12].*

Communities	**Environment**	**Business**
Expanded local business opportunities	Continuous environmental improvement	Higher profitability
Larger tax base	Better resource use	Enhanced market image
Community pride	Reduced waste	High performance workplaces
Reduced waste disposal costs	Innovative environmental solutions	Improved environmental efficiency
Improved environmental health	Increased protection of natural ecosystems	Access to financing
Recruitment of higher quality companies	More efficient use of natural resources	Regulatory flexibility
Improved health for employees and community	Continuous environmental improvement	Higher value for developers
Improved environment and habitat	Better resource use	Reduction of operating costs (energy, materials and water)
Partnership with business		Reduction in disposal costs
Minimized impact on infrastructure		Income from sale of by-products
Improved tax base		Reduction of environmental liability
Enhanced quality of life in area near eco-industrial development		Improved public image
Improved aesthetics		Increased employee productivity
Good Jobs		Higher profitability
Expanded local business opportunities		Enhanced market image

Of course there are also costs, risks and challenges in EIP development due to its inherent complexity. Governance, for example, is an important issue when many companies have to take decisions together. Cultural differences are also challenging as well as interdependence and investments required. Eco-Industrial Parks are initiatives for the long term since most benefits will appear only in 5, 10 or 15 years, and the challenges are concentrated at the beginning when engaging companies and communities.

When we compare positive and negative outcomes at existing EIP, it becomes clear that they are mainly positive to all stakeholders involved. Besides, despite the name "Eco" as well as original "symbiosis" concepts being usually connected to environment, the benefits are broad and reach also social and economic areas. When developing Eco-Industrial Parks, a systemic approach is essential to capture the totality of value that can be generated by them.

Business Externalities

Companies referred to as leaders in sustainability are those which bear responsibility on their externalities, Externalities is the term used to signal the "side effects" on the operations of a business, whether positive or negative ones. They are the impacts a business produces in broad terms, be it directly or indirectly, but not being obliged to pay for them, or rather, consider them during their decision-making processes. [15]. "Externalities are those consequences of a production process, imposed on society or the environment, which are not taken into account in the product price. They are produced whenever production processes, or consumers` utility, are affected by variables not controlled by themselves, but by other economic agents. These effects may be positive (external benefits) or negatives (external costs)" [14], p.469.

Three current factors have driven the society to act with greater force in the control of externalities generated by companies. First, the continuous increase in economic activity in recent decades, with ever greater production scales. More natural resources are removed to meet the needs of developing countries and simultaneously, a larger quantity of pollutants is released into the biosphere. This reality is evident when one compares, for example, oil consumption in the post-war period with the current levels or, when considering the growing accumulation of greenhouse gases in the atmosphere. Secondly, the increasing amount of sensors that make it possible to monitor all the relations of man with the environment, allowing, for example, the monitoring of the different chemical compounds produced by the companies and their effects. In addition to the pollutants in the atmosphere, there has been started the control of the effects of companies on the physical environment, which includes not also the physical degradation of environments but also the unsustainable exploitation of natural resources. "The United States AQS (Air Quality System) now stores data from more than 5,000 active monitors on 188 pollutants—and anyone can register to use these EPA data, free" [14] p.4. Finally, another important factor to foster a better control of externalities is society's engagement on the challenges of sustainable development, which has already resulted in several actions of businesses responsible for their mistakes and deviations that eventually lead to externalities. An example is the mobilization of Web 2.0, a situation in which social networks pressure companies and public authorities in order to provide causes which may bring about better social and environmental conditions for the present and future.

The activities generating externalities can create positive or negative consequences on the stakeholders (Table 2). If positive, the social benefit provided by the business exceeds the traditional view of economic gain, and creates private social welfare for other stakeholder groups. In contrast, the activities that produce negative externalities end up penalizing different groups without their being able to enjoy any compensatory benefits coming from the activities of the business. As mentioned by Sankar [13] in situations with negative externalities, the social cost of business is higher than the private cost paid by them.

Table 2. *List of business externalities [18,19].*

Business area	**Activity**	**Externalities**
Power plant	Coal burning	Economic development, job creation, pollution
Casino	Gambling	Job creation, tourism development, urban revitalization, crime, corruption, suicide, bankruptcy
Motor vehicle use	Mobility	Economic development, job creation, trade increase, air pollution, pain, suffering, death

For example, a negative externality of a power plant that is otherwise producing a useful good for society is the air pollution it generates. In traditional economics, the harmful effect of the pollution, e.g. smog, acid rain or global warming, on human health and the environment is not factored in as a cost in the overall economic equation. For decades environmentalists have argued that economics should take into account the costs borne by such externalities in order to discern the true overall value to society of any given action or activity [16]. In this sense, different parts have argued that the company or utility that operates the polluting factory should be required to compensate the larger society by paying for the pollution it produces so as to offset the harm it does. Pollution represents an external cost because “damages associated with it are borne by society as a whole and are not reflected in market transactions” [17]. “So-called “cap-and-trade” schemes are one real-world way of monetizing a negative externality: Big polluters must buy the right to generate limited amounts of carbon dioxide (and they can trade such rights with other companies that have found ways to lower their carbon footprints, thus creating an incentive for polluters to clean up their acts)” [16], p.1.

Thus, one can say that economic development has brought a number of problems, or "side effects". According to the guide The Natural Step (TNS), this scenario is known as "the challenge of sustainability." Also according to TNS, the systemic conditions for sustainability depend on four factors: in a sustainable society, nature is not subject to systematically increasing concentrations of substances extracted from soil (1), the accumulation of substances produced by society (2) and physical degradation of natural areas (3). Nevertheless, people should also be able to meet their needs (4) [18].

The systemic view of sustainability proposed by TNS has the role of showing the main lines to be followed by companies so as not to generate negative externalities. The perpetuity of enterprises depends on a positive balance of externalities, since only by ensuring a harmonious coexistence with their environment, may the companies receive a license to continue existing. May any phenomenon happen that make the sustainability of systemic conditions impracticable, negative externalities will emerge. In order to deal with scenarios like these, one shall adopt an approach to control the externalities. Figure 1 shows the main steps to be followed in order to act on the externalities of a business.

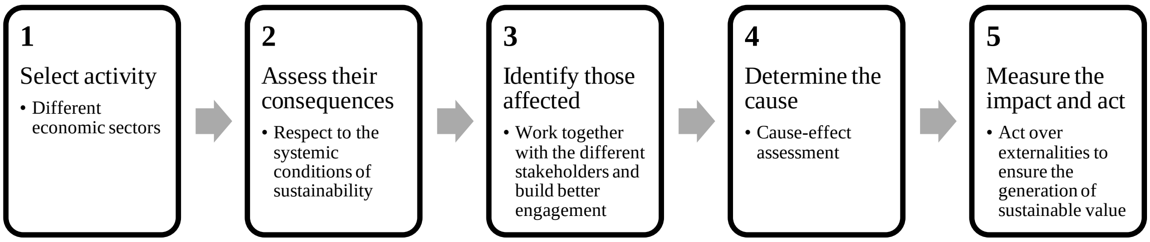

Fig. 1. *Way to control business externalities.*

By using the above approach to deal with externalities, one can enjoy good opportunities, be they represented by tangible gains, i.e those associated with resource savings, or by intangible benefits, i.e benefits for the brand and better risk control. Sustainability actions designed to act on some externalities may simultaneously generate both tangible gains and intangible gains.

Externalities control as a driver for industrial symbiosis development

As it is in previous sections, the growth of world industrial production has brought a series of negative developments, or "side effects", also known as externalities. Within this context, retrieving and controlling pollutants has become insufficient, so it becomes necessary to direct efforts to reduce them and, especially, to prevent discharge of harmful substances into the environment. This is because the products and waste are discarded into the environment without there being decomposers and recyclers for them.

This accumulation of unwanted material into the environment characterizes the industrial system as an open system. An objective of the industrial ecology is to transform the linear character of the industrial system into a cyclic system, in which raw materials, energy and waste will always be reused [23]. According with Beers et al. [24], one way to reduce emissions or disposal of wastes to water and atmosphere is through the realization of industrial symbiosis, also referred to as regional resource synergies. These concern the "capture, recovery and reuse of previously discarded by-products (materials, energy and water) from one industrial operation by other, traditionally separate, industries operating in their close proximity [24], p.831.

The desire to change the material flow from a linear view into another cyclic or circular one, is the target of the industrial symbiosis. It becomes an appropriate way to contain the generation of negative externalities of industrial activities over the population, respecting thus the systemic conditions of sustainability (Figure 2). It is believed that industrial symbiosis has the potential to both benefit the economy and substantially relieve environmental pressure in and near the location of its development [21].

As it is shown in Figure 2, an appropriate way to develop symbiotic relationships between enterprises in different economic sectors is based on the identification of negative externalities which penalize one or more groups of individuals to then enable actions that transform the problem into a new opportunity of revenue generation and / or intangible gains. The latter can be divided into four distinct types of gains, the relationship capital, institutional capital, organizational capital and intellectual capital. All of them may favor the company's positioning in the market, either through profits in reputation, or an improved risk management, or through new opportunities to generate revenue or minimize costs.

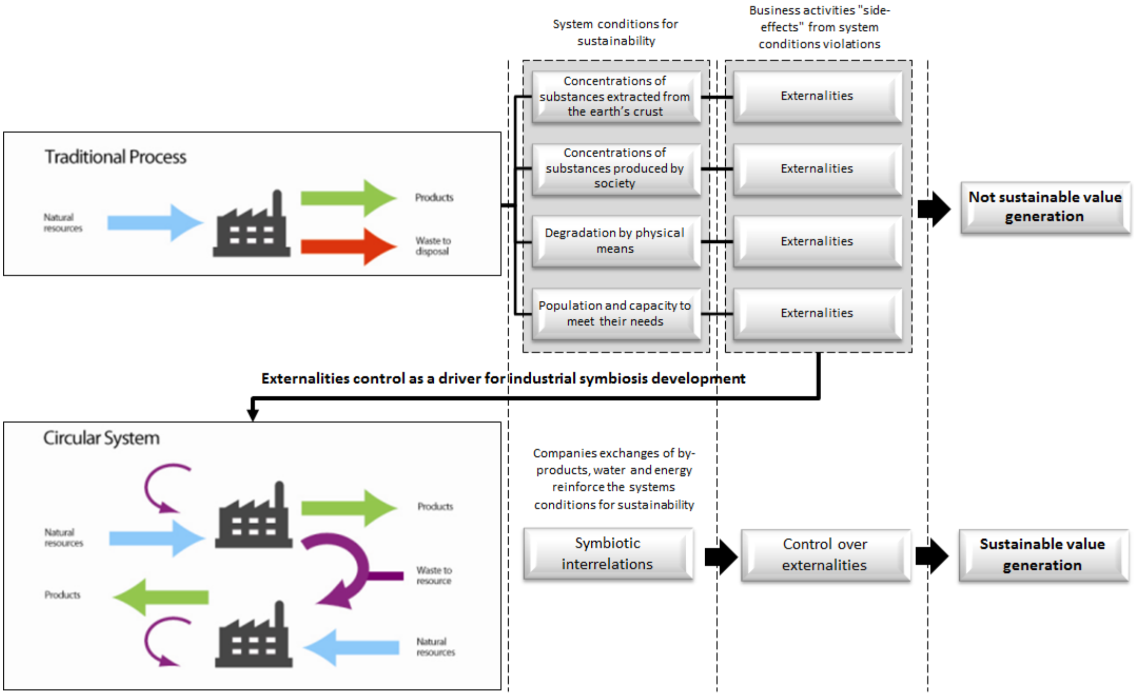

Fig. 2. *Externalities control as a driver for industrial symbiosis development.*

Thus, industrial symbiosis could be the adequate way for companies to respond to their externalities, starting to contribute to sustainable value generation. For change to be permanent, it is necessary that all parties are engaged and see value, tangible or intangible, on the improvement of their processes, and in the strengthening of partnerships between enterprises belonging to different supply chains.

Hence, Table 3 was created in order to bring real examples coming from industrial symbiosis in the world, which were able to cope with longstanding externalities for the type of industry. This table was constructed following the logic of the five steps of approach of externalities, starting from its major externalities and their affected kinds of public, to later understand its causes and then act on them. Recalling that in Figure 1 an approach was presented, in a summarized form, for the control of externalities through which it is possible to systematically understand the consequences of the activities of a type of business over the groups of individuals, and the cause and effect relationship which led to its appearance.

The case of the power plant in Denmark, which used to lose some of the heat generated from coal without there being some kind of compensatory benefits for the company and society, is a good example of how industrial symbiosis has come to bring economic, environmental and social benefits to stakeholders. In this case, the company, in partnership with the city of Kalundborg, invested in numerous underground pipes so that the heat that used to be wasted would be taken to the residences in the city, which in turn allowed better energetic efficiency to the burning process. The externality associated with the non-efficient consumption of non-renewable resources has been circumvented, and used to generate additional revenues, reduce the population cost of living and, more importantly, to make disappear the environmental impact of burning fuel oil in residential buildings, no longer existing. Other examples of externalities and industrial symbiosis were selected for the mining, petroleum and chemical sectors.

Table 3: *Main business externalities and alleviation acts via industrial symbiosis [12,13].*

Business sector and location	**Main externalities**	**Stakeholders affected**	**Causes**	**Industrial symbiosis**	**Sustainable value generated**
Mining; Alumina refineries (Gladstone, Australia)	Use of water from local reserves during drought	Population near the industrial plant; shareholders; Gladstone city hall	Alumina is produced from bauxite using water from local sources	8.5 km pipeline so that secondary treated effluent from Gladstone sewage treatment plant could be used for its mud washing process	During drought alumina refinery was able to continue to operate at full production; no need to install tertiary treatment AT Gladstone sewage treatment plant; water source conservation; no city effluents discharged to local waterways
Energy; power plant (Kalundborg, Denmark)	Inefficient energy generation	Population near the industrial plant; shareholders; Kalundborg city hall	1,500-megawatt coal-fired power plant disperse thermal energy to atmosphere	Distribution of heat from the power plant through a network of underground pipes	Town of Kalundborg has eliminated the use of 3,500 oil-fired residential furnaces; homeowners pay for the reliable heat in return; cut in power plant GHG emissions
Petroleum; oil refinery (Kalundborg, Denmark)	Resource waste during refinery process	Population near the industrial plant; shareholders	Refineries during production of petroleum products has the common practice of flaring waste gases	Refinery has been piping the gas to wallboard plant to fire drying ovens	Wallboard plant cut expenses and GHG emissions from atmosphere; Power plant revenue from distributed gas
Chemical; production of titanium dioxide (Kwinana, Australia)	Production of contaminated acid water	Population near the industrial plant; shareholders	The manufacture of titanium dioxide pigment generated a dilute hydrochloric acid	Hydrochloric acid reuse	Revenue from sale; avoided treatment costs; water source conservation

Final Remarks

The proposed contribution of this paper was to show how a different approach to Eco-Industrial Parks and Industrial Symbiosis development can increase significantly their potential benefits. Traditional methodologies work on exchanges and infrastructure and services sharing while focusing on eco-efficiency and tangible economic benefits. While this approach has had an important role to create value to engaged companies, it could be improved incorporating externalities and sustainable value concepts.

The difference might seem subtle, but when industrial symbiosis studies start from externalities mapping, the spectrum of opportunities is significantly increased due to its systemic view. Benefits could go from eco-efficiency, cost reduction and increased revenue to intangible value such as relationship, institutional and organization capital. To clearly show these aspects, the paper proposed to use the sustainable value concept, dealing not only with tangible, but also with intangible value. A broad value generation concept can help companies to visualize the totality of the opportunities associated with Industrial Symbiosis and Eco-Industrial Parks.

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