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Industrial Ecology as an Integrated Framework for Business Management

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Abstract

Growing global concerns about a plethora of environmental and social problems related to working circumstances, health, safety and inequity have currently fostered sustainability approaches for industry. Sustainable industrialization has emerged as a new strategic trend for facilitating socio-economic benefits without impairing basic environmental quality. This change in paradigm has led to a new concept in industrial sector called “Industrial Ecology” (IE). Based on a straightforward analogy with the natural ecology, IE aims at transforming open linear industrial systems towards closed, cyclical independent systems. With a multidisciplinary scientific approach and many practical tools and strategies, it addresses various cross cutting themes related to pollution and environment and the entire spectrum of issues that are involved in the management of enterprises. The delineation of various concepts synthesized in this paper reveal a largely untapped potential of IE as a promising integrated framework for managing industrial practices.

Keywords: Industrial Ecology, Sustainability, Integrated framework, Business, Management, Corporate Environmentalism, Waste.

1. Introduction

As a consequence of 14 fold increases in trade and rapid industrialization since 1985 and the expanding economic growth, natural resources are consumed faster than they can be restored, while wastes and pollutants are released faster than the earth can absorb them. Industrial activities are increasingly in confrontation with ecological systems (O'Rourke *et al.* 1996).Growing global concerns about a plethora of environmental and social problems related to working circumstances, health, safety and inequity have currently fostered sustainability approaches for industry. Rapid industrialization, open market, high quality requirements from customers, legislations and an increase in competitiveness between companies locally and globally have created a serious demand for a structured design for product as well as process innovation within industry. There is an urgent need of an approach that allows the environment and development to co-exist without threatening each other’s viability (Tibbs 1993). Sustainable industrialization has emerged as a new strategic balanced and dynamic developmental trend for facilitating socio-economic benefits for present generation without compromising the needs for future generation and without impairing basic environmental quality and ecosystem processes/services. This change in paradigm has led to a new concept in industrial sector called “Industrial Ecology” (IE), a field just about twenty two years old.

In the subsequent sections this paper discusses theoretical dimension of industrial ecology related to business management based on a content analysis of the articles published so far in various journals, complemented by other papers relevant to this discussion. With focus on basic proponents of industrial ecology along with a glimpse on the tools and strategies developed under this field, we try to outline the

integrative nature of this framework towards the overall management of business sector.

2. Defining IE and its vision

IE is defined as the system-oriented study of the physical, chemical, and biological interactions and interrelationships both within industrial systems and between industrial and natural ecological systems. The idea of IE is based on a straightforward analogy with the natural ecological system (Graedel & Allenby 1995). Based on the nature's principle that "nothing is being wasted as waste from one species becomes food for another species", IE studies industrial systems as industrial food webs and examines the potential application of natural models for the development of industrial processes and products (Nakajima 2000**;** Berkel *et al*. 2009)**.** It aims at transforming traditional, open linear industrial systems towards closed, cyclical and interdependent systems, paralleling nature.

The purpose of IE is forward-looking: rather than focus on remediation of past ills or end of pipe controls on pollution already created, it stands for avoiding environmental damage in the first instance through systems analysis, through product, process, and facility design, and through technological innovation (Chertow 2007). It aims to look at the industrial system as a whole. It not only addresses issues of pollution and environment but considers as well the entire spectrum of issues that are involved in the management of enterprises, ranging from technologies, process economics, inter-relationships of businesses and financing to overall policy (Erkman *et al*. 2001).It seeks to optimize the total materials cycle from virgin material to finished material, to component, to product, to obsolete product, and to ultimate disposal (Graedel & Allenby 1995). This innovative concept goes beyond a more efficient management of waste to encompass all activities in a given system, including resources (extraction, optimization, productivity, and recovery), processes (production, manufacturing, distribution, consumption), and disposal (collection, re-processing, final disposal) (Wernick & Ausubel 1995; Frio 1998).

At its core, IE studies and interprets industrial system in two ways: first, as the activity of transforming resources into products and second, as the collection of companies involved in extracting, processing and manufacturing products and delivering services. It focuses on identifying and quantifying flows of materials and energy across the entire industrial cycle, ensuring they are used efficiently and effectively, providing for the needs of humanity while promising that the assimilative capacity of the planet is not overwhelmed (Cote *et al*. 2006). By displaying trends, scales and relations of materials consumed, emitted, dissipated and discarded, it can generate different scenarios which in turn exposes opportunities to better the performance of industrial ecosystems (Wernick & Ausubel. 1995).

Actually opinions vary from literature to literature on conceptualization of IE, but all authors agree more or less that there are five key concepts of industrial ecology perspective which focus on:

1. Design of products, processes, facilities, infrastructure, services, and technology systems so that they can be easily adapted to environmentally preferable innovation with minimal waste.
2. Minimization of waste production and resource consumption in all activities.
3. Use of the least toxic alternatives whenever possible, particularly when the materials may be dispersed into the environment.
4. Design of products, facilities, infrastructure, and technology systems to preserve the embedded utility of materials and energy used in initial manufacture. Thus, in many cases designs which extend the life of products and support the recycling, recovery and reuse of subassemblies or components, rather than materials, are preferable.
5. Design of physical products at all scales not just to perform their intended function but also to be used in creating other useful products at the end of their current life.

3. Tools and Strategies for IE

IE is a multidisciplinary applied science which comprises system analysis through laying its foundation in

basic sciences, system engineering, economics, law, management, as well as social sciences. Many important practical tools that can complement and enhance an integrated framework for sustainable business management have been developed in the field of IE (Hond 2000; Poyyamoli & Patnaik 2010). The following section gives a brief characterization of these tools:

Materials flow analysis (MFA) or Substance flow analysis (SFA) is basic analytical tool of industrial ecology which uses numerical data for direct inputs of materials, in combination with chemical or engineering details of the processes being studied for analyzing resource flows. It is based on the fundamental physical principle that matter can neither be created nor destroyed. Therefore, the mass of inputs to a process, industry or region equals the mass of outputs as products, emissions and wastes, plus any change in stocks.

Life cycle assessment (LCA) is used to determine the total environmental impact of a product throughout its life cycle (i.e. from cradle-to-grave). There are three basic stages in LCA: inventory analysis, impact analysis, and improvement analysis.

Strategic Environmental Assessment (SEA) is conducted to ensure that the environmental consequences of proposed policies, plans and programmes are within prescribed limits and allows the integration of sustainability objectives at the earliest stage of the decision-making process.

Environmental Risk assessment (ERA) estimates the inherent hazards involved in processes or situations and the risks posed by these either quantitatively or qualitatively. It includes human health risk assessments, ecological or eco-toxicological risk assessments and specific industrial applications of risk assessment. ERA includes a number of steps:

- Problem formulation
- Hazard identification
- Release assessment
- Exposure assessment
- Consequence assessment
- Risk estimation/ evaluation
- Risk characterization/management

Ecosystem vulnerability analysis reveals the degree of capability and sensitivity of an ecosystem to cope with the consequences of natural changes.

Eco-performance profile is the identification of energy and material-related environmental impacts generated by the company and along products' life cycles, cradle to grave**.** Full environmental cost accounting includes physical flow accounting and monetary flow accounting. The former deals with material and energy flows, and the latter deals with evaluation of environmental impacts, cost of damages to the environment, cost for environmental protection activities, and so on.

Environmental auditing is a management tool that is a systematic, documented, periodical, objective evaluation of how well the environmental protection organization, management procedures, and equipment function in protecting the environment by facilitating the management control of environmental procedures and evaluating conformance with the company's environmental policy, legislation, permits, and so on.

Eco-mapping is a visual, simple, and practical tool to analyze and manage the environmental performance of the industry; an easy, creative, and systematic method of obtaining environmental data based on the physical reality of the industry; and a dynamic inventory of the changes in the environmental behavior of the industry in a visual format.

Total quality environmental management is a management philosophy and a set of accompanying quality improvement techniques that have been widely used in various sectors all over the world. Total quality means an ultimate goal of zero pollution, whether for the individual firm or for a cluster of companies in an industrial ecosystem, undertaken continuously for improvement across all operations by seeking to discover

the reasons for poor quality performance and implementing methods to reduce and/or eliminate the causes of poor quality.

Environmental health and safety (EH&S) is used for reviewing legislation, recommending policies, and monitoring compliance with environmental and health and safety statutes and regulations. Environmental management system *(EMS)* is part of a management system of an organization in which specific competencies, behaviours, procedures, and demands for the implementation of an operational environmental policy of the organization are defined. It improves the overall performance and efficiency of a company. It also facilitates cost savings through the reduction of waste and more efficient use of natural resources and avoids fines and penalties from not meeting environmental legislation by identifying environmental risks and addressing weaknesses. It improves the public image of the enterprise.

Integrated environmental strategies provide policymakers and other stakeholders with quantified data on the health, environmental, and economic impacts of selected integrated measures. Integrated environmental strategies lay the groundwork for implementation of policy, technology, and infrastructure measures with significant local and global benefits.

In addition, there are other proven strategies, such as:

- Clean/green technologies (clean development mechanism, zero waste, etc.)
- Dematerialization
- Design for environment
- Design for sustainability
- By-product exchanges /Industrial symbiosis/Eco-industrial park
- Environmentally sound technologies
- Corporate environmental/social responsibility
- Eco-industrialization
- Supply chain management etc.

These developments signal an international shift in emphasis from managing individual manufacturing wastes and emissions to managing the overall environmental impacts of industrial sectors and of products over their life cycles. Moreover, as the importance of both information technology and the technological infrastructure are increasingly recognized, application of IE is making progress from its initial emphasis on specific products and materials to a broader emphasis on infrastructure, technological systems, and resource efficiency of the whole system (Poyyamoli & Patnaik 2010).

4. Benefits of IE to business

Adopting IE perspective may enhance a firm's competitive position through sustainable gains at three levels: within the firms's value chain, within the value system it shares with its suppliers and distribution channels and beyond the chain of production (Frio 1998; Hond 2000).In the following sections we will discuss about it with greater details.

4.1Revenue generation

Companies are sometimes unaware that their by-products have market value and can be sold rather than disposed of. Applying IE principles through byproduct-exchanges, or simply by investing in technologies that will facilitate such exchanges, companies can gain good monetary benefits (Frio 1998).

4.2 Cost savings

Industrial ecology spurs attention to new/hidden opportunities for cost savings that would have otherwise gone unnoticed. It sparks creativity and innovation that leads to unanticipated benefits that go beyond waste

minimization.

In a successful industrial ecosystem the eco-industrial economic gains lie in the reduction of raw material and energy costs, waste management costs and costs resulting from environmental legislation, as well as the improvement in working conditions and 'green market' potential' (Korhonen 2001).A company can realize peso savings through minimization of inputs, substitution of materials, and reduction of disposal costs. If the end result of these savings is a lower product price, this can increase the competitiveness of the firm, expand the market share, and satisfy customers. Likewise, improved public image can also increase market share and equity value (Frio 1998).

By giving attention to the flows of materials and energy through a firm's possibility of closed loop systems and design for environment opportunities, it can add to the value of a product or reduce the cost of production. Thinking in industrial ecology terms may also help improve resource productivity by enabling a firm to redefine a product and increase its value to customers. By cutting costs or generating value for suppliers or customers, companies are often able to improve their competitive position.

The sharing of materials, energy, and water can yield significant costs often with little or no capital investment. Cost savings can also be realized through the shared capital and operating costs of utilities which supply gas, water and other services to companies. By combining purchases of shared inputs, firms may also be able to negotiate better prices.

4.3 Reduced liabilities

Both financial and legal liabilities can be minimized through industrial ecology. Better environmental activities can reduce payments related to higher risk premiums and improve a firm's credibility. Waste reduction may reduce liabilities related to environmental accidents or improper disposal. A firm implementing IE practices can also avoid penalties and liabilities imposed by the local and national government.

4.4 Improved opportunities for new investment

Potential investors gain advantage if a strategic plan for an industrial symbiosis is laid out. Sharing, recycling, recovery and reuse of materials, energy, and water open up new opportunities for potential investors to create a clean and green business atmosphere with huge employment potential. The development of innovative solutions, products, processes, technologies and materials will allow more firms to expand into new markets.

4.5 Enhanced public image

A company consciously employing industrial ecology in its systems gains an edge over its competitors. Practicing corporate environmentalism empowers a firm to recognize that this conviction can be compatible with good business. With enhanced protection of natural ecosystems, habitats and more efficient use of land, water, energy and other natural resources, it possesses reduced risks to health and safety of employees and human communities. It helps in enhancing a company's relationship with the community, suppliers, customers and the local and national government (Frio 1998; Clayton 2002; Nolan 2006).

5. Conclusion

Industrial ecology is an emerging integrated approach which addresses environmental concerns brought on by rapid industrialization. It is an innovative concept for designing and operating industrial systems as living systems interdependent with natural systems**.** It is an attempt to combine both product competitiveness and environmental improvement by shifting from a linear to a materials cycle approach (Gibbs *et al*. 2005; Cote *et al*. 2006).

This new business-oriented initiative develops a systems approach to efficient resource use and protection of the environment, with focus not only on devising improved methods of waste treatment and disposal but also on the best opportunities to reduce waste throughout the total material cycle from virgin materials to finished products to end of product life (US environmental Protection Agency 2000). It provides the scientific basis upon which is based the understanding of current business practices and evaluation of ecologically sound innovation **(**Clayton 2002; Hauff &. Wilderer 2008). With various practical tools and strategies, it addresses cross cutting themes related to pollution and environment, along with technologies, process economics, the inter-relationships of businesses, financing, policies and the entire spectrum of issues that are involved in the management of enterprises.

This innovative concept brings a sustainable strategy to competitiveness where the company improves its triple bottom line through enhanced socio- economic and environmental performance. It identifies untapped value-added opportunities and business models that work to address sustainable issues for future industrialization particularly through corporate socio-environmental responsibility (CSER). It reduces production/ material/ energy/ treatment costs and liabilities; improves operating efficiency, quality, worker health, and public image; and provides opportunities for income generation from better utilization of wasted materials. The benefits include the exploitation of underutilized by-products into useable by-products, improving human resource, reducing infrastructure, operation and maintenance costs and maximizing the use of energy/material flows which in turn will minimize the ecological footprinting of the region. All these factors improve the competitiveness, investment attraction, job security, business retention, and community wellbeing, thus facilitating overall sustainability within a specific regional context. It could help policymakers address some of the core challenges of industrial sector, ranging from climate change to waste management to social responsibility.

Additionally it offers options, which are effective for increasing profitability by optimizing the use of scarce indigenous resources while reducing environmental problems. Thus, industrial ecology is especially relevant for developing countries, where rising populations with increasing economic aspirations and growing management demand should make the best use of limited resources. The utility of this approach can also be phenomenal in the context of developing countries as it provides a much needed option for them to plan be shrewd and leap frog into the new era of ecological economy that has just dawned (Graedel 1996; Erkman *et al*. 2001)**.**

In short, industrial ecology deals with the problems facing by the sector to which it is applied and creates a framework that allows business to contribute effectively to sustainable management. On a larger picture, industrial ecology is a tool to achieve a delicate balance between rapid industrialization and quality of living, not only of the present generation, but more importantly of the future's. But more significantly, it has opened doors to rediscovering "the common sense of business" (Frio 1998)**.**Through changing production mode, consumption behavior with a new line of thinking and developing decision instruments based on ecological economics and system engineering, it renovates ecologically sound and economically effective strategies and technologies for planning, designing and development of eco-industry and provides an integrated framework for overall business management. As a result of combination of advantages, industrial ecology is predicted to be one of the key business management strategies for the next century.

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