The Landscape of Industry: The Transformation of (Eco) Industrial Parks through History

Archana Sharma[1]

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ABSTRACT

The landscape of industry has been changing over time. Industry has transformed, and many tangents have emerged, from the sporadic home-based cottage industries to geographically scattered large manufacturing industries to co-located industrial parks to environment-friendly eco-industrial parks. Curiosity about the catalysts that bring about the transformation of industrial landscapes is the motivation of this article. Through the narrative on industrial parks and the gradual shift toward eco-industrial parks, this article aims to shed light on the context and conditions that act as catalysts for industrial transformations so as to serve as a reference for predicting future changes in industrial landscapes.

1. Introduction: Industrial Park

An industrial park (IP) is a tract of land that is subdivided and developed systematically, according to a comprehensive plan, to provide serviced sites for a community of compatible industries, as per most dictionary definitions. They may range from open acreage that the developer sells as lots to fully controlled developments in which buildings and sites are leased to the occupants and may be spread over anarearanging from 10 acres to over 2,000 acres.

Terms like 'industrial districts' and 'industrial estate' appear quite often in literature on the history of industrial parks.'Industrial districts,' 'industrial estate,' and 'industrial cluster' are alternative terms for 'industrial park,' whereas 'business park' [1] and 'science and technology park' [2] are further sub-classifications of an 'industrial park' based on the type of industrial activity (UNEP 1996). Industrial park was defined as below at the Urban Land Institute's, 1958 Dartmouth conference*(ULI, 1988):*

> *An industrial park is a planned or organized industrial district with a comprehensive plan designed to ensure compatibility between the industrial operations therein and the existing activities and character of the community in which the park is located. The industrial park must be of sufficient size and be suitably zoned to protect the areas surrounding it from being devoted to lower uses.*

The National Industrial Zoning Committee[3] definitions through1952, 1965, 1966, focused on shared land resource and common administration (ULI 1988).

> *An industrial park is a tract of land, the control and administration of which are vested in a single body, suitable for industrial use because of location, topography, proper zoning, availability of utilities, and accessibility to transportation.*

The essential idea of sharing resources was still retained. Fundamentally, several industries pooled their infrastructural resources such as transportation and waste facilities to survive the economically difficult years that followed the Second World War (ULI 1988). These conglomerations of industries were popularly known as "industrial parks." The members of these parks shared a tract of land and divided the cost of infrastructure such as land, roads, and drainage-ways among themselves. As a conglomerate, the industries also assumed collective responsibility for matters that concerned any or all of them. For example, the cost of waste disposal was high during the postwar period. More recently, there has been further innovation in industrial operations manifested through the construction of eco-industrial parks.

[1] Morgan State University, United States

2. Method

This paper narrates the history of industrial parks and eco-industrial parks with the purpose of extricating and understanding the context that affects the transformation of industrial landscapes. The study is conducted through a critical literature review, case studies, field research in Kalundborg, Denmark, and personal interviews with various stakeholders, which are all integrated in the narrative. Meta-analysis and deduction are used in conjunction to understand and explain the evolving landscape of industry.

3. Catalysts for Industrial Parks

Industries around the time of industrial revolution were but an encroachment upon the urban spaces of cities as they grew from backyard activities into full-fledged industrial operations (Mumford 1961). Industrial employment–based migration to cities led to crowding of habitable areas in the proximity of industries. The idea of clustering together the pollution or the pollution-generating industries must have emerged as rational for the time. Separating the industrial areas into highly pollutive and non-pollutive would have followed naturally. While non-pollutive industries could be housed within the city (or would not need to be removed from the city), separating the pollutive industrial areas from residential areaswas being recommended. Greenbelts and park strips were proposed as buffer elements for functional segregation and visual integration of urban/rural andnon-pollutive/pollutive industrial areas. These zoning decisions could easily be interpreted to have subtly shaped the ideological and physicalconstruct of an industrial park.

The collective expenditure for infrastructure such as roads and drainage ways was an economic easement for all the firms involved in such a "sharing."Escalating costs of doing business in inner cities forced the expansion of industries on the outskirts. The suburbs offered the firms cheaper labor, cheaper land, and large tracts of undeveloped land, which made the expansion there more efficient and productive (National Council for Urban Economic Development 1995). Hence, pushing the industrial zones toward the periphery was agreeable to industrialists as well as planners because of cheaper land/labor, expansion possibilities, and segregation of pollution generators.

The need for more appropriate allocation of land according to a specialized segregation of the different functions grew into a differentiation of districts for residential, industrial, and commercial purposes (Gutkind 1943, 90). Escalating costs of doing business in inner cities may have been an outcome ofa judicious planning policy to facilitate functional segregation between industrial and residential areas.

To avoid the fragmented look of urban spaces created by strict functional segregation, the concept of a greenbelt was adopted for the visual integration of spaces. Gutkind(1943) distinguished the underlying principle of this "green grid" from the point of view of the layout as splitting up the structure of the towns into a number of "self-contained" communities. Gutkind stressed that the principle of splitting up urban settlements by a green grid must not lead to a separation of parts that belong together structurally. The growing human population has induced the expansion of cities toward the outskirts. The suburbs housing the industrial parks might soon urbanize, hence making the industry-civic interface more crucial. In such a situation, the need for industrial setups with minimal or negligible negative impacts on the immediate environment becomes exceedingly important.

So while many more companies were coming together to form industrial parks, the pollution statistics were looking grim. Environmental degradation became a matter of intense debate. Rachel Carson's book *Silent Spring* (1962) generated unprecedented public awareness of the consequences of environmental degradation. Combined pressure from academic and public opinion forced government and nongovernment bodies into action. The Environmental Protection Agency was established in 1970 in the United States of America, and organizations such as the World watch and Earth watch Institutes were founded in 1974, and the United Nations sponsored a conference on the human environment in Stockholm in 1972. The findings of these and similar organizations indicated that industries were responsible for polluted and resource-depleted environments. As a result, new directives were formed for regulating industry.

In America, laws were framed to address the problems due to industrial pollution. The implementation of government policies and laws for cleaner production within industries was scrutinized more strictly.However, legal scholar Christopher Stone observed during the mid-1970s that environmental laws could never regulate companies because laws only react to situations and obviously cannot prevent problems. Environmentalists like Ralph Nader and Barry Commoner also shared similar opinions regarding EPA laws. According to them, limiting pollution at the end of the pipe was not as good as simply banning polluting substances. The concept of risk analysis which proposed "acceptable levels" of pollution advocated by the EPA was unacceptable to many environmentalists because it froze levels of pollution in place and prevented industries from innovating in terms of pollution reduction,prevention, and ultimately, elimination (Lamprecht 1997, 25), thus decrying further rethinking on industrial practices and policies.

4. Catalysts for an Eco-Industrial Park

The International Organization for Standardization, the United States Environmental Protection Agency, and the United Nations set a new agenda for industries with an emphasis on pollution prevention, waste reduction, and energy conservation. Industrial parks were forced to conceive of new strategies and initiatives to reduce waste and pollution.

One of these initiatives pertained to waste management. This engagement with matter and energy exchanges causeda paradigm shift in which the industrial park evolved into an eco-industrial park.

In a way, the newer politically driven context of environmental consciousness created conditions for innovative thinking, even though forced. It is in this context that Frosch and Galloupolos reoriented the discussion on sharing resources to exchanging resources by approaching "waste as resource" along the lines of a food web (Frosch and Galloupolos 1989,144–152):

> *The traditional model of industrial activity, in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of, should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized and the effluents of one process, whether they are spent catalysts from petroleum refining, fly and bottomash from electric power generation or discarded plastic containers from consumer products, serve as raw materials for another process.*

The concept applies the process of symbiotic exchanges to industrial establishments. All this required was to extend the practice of sharing land, roads, and drainage ways within an industrial park to raw materials and waste recycling and shift the approach from resource sharing to resource exchange, thus minimizing waste and associated pollution generation. The renovated industrial idea or establishment was called an "industrial ecosystem" or an "eco-industrial park." While the more generic term 'industrial ecosystem' includes regional and global inter-industrial exchanges, the term 'eco-industrial park' customarily refers to an industrial park that incorporates inter-industrial exchanges within definite site boundaries at the local level. The eco-industrial park represented a shift from the traditional linear model of "raw material to industry to waste" to a closed-loop model of "raw material to industry to waste to raw material to industry B," in which the waste from one industry became the raw material for an other industry. The planned materials and energy exchanges in a generic eco-industrial park conserve energy, economize on the use of raw materials, minimize waste, and build sustainable economic, ecological, and social relationships. Kalundborg Symbiotic Industrial Park is one of the best-known examples of an eco-industrial park. Many other existing and potential eco-industrial parks have been identified and planned worldwide(Erkman1997; Ayers1996).

As SurenErkman(1997) noted, "The ideas presented in Frosch and Galloupolos' article were not, strictly speaking, original but it can be seen as the source of current development of industrial ecology." Another source of reinvigorated interest and acceptance in the concept of "waste as a resource" came from Kalundborg in Denmark and emerged organically in reaction to the political, environmental, and economic contexts and inadvertently led the most poignant industrial transformation of this age by example.

In the 1970s, when the concept of the industrial park was being adopted and experimented with sporadically, Kalundborg in Denmark developed as an industrial park. Grant provides a good review of Kalundborg (Grant 1997, 75–78). The major industrial player in Kalundborg was a power plant supplying its by-products, heat and water, to an oil refinery and a pharmaceutical company. The by-products, such as gypsum and fly ash, were used by wallboard plant and cement industry. Excess heat from the power plant is also used to heat up the fish farms and residences of Kalundborg citizens. A supply of gas and sulfur from the oil refinery to the power plant, wallboard plant, and sulfuric acid plant, respectively, forms the secondary level of exchanges. Sludge from the pharmaceutical company is distributed to farmers for field applications. This ambitious initiative, however, does not come fool proof and often has issues that need resolution, such as higher cost for heating hoses than predicted, finding users for many waste products (Grant,1997).

5. The Current Landscape of Eco-Industrial Parks

To further understand the broad intellectual and operational landscape of eco-industrial parks, about 15 other industrial projects aspiring to be eco-industrial parks were studied; findings are discussed as follows.

5.1 Operational Design

Life cycle analysis, design for the environment, and dematerialization are essential design tools guiding the planning and development of eco-industrial parks. A life cycle analysis studies the life and the environmental impact of a product, from its inception through its disposal and the impact on the environment at all intermediate stages of its production, thus identifying the production stages that create the most and the least amount of pollution. The approach of design for the environment involves modifying and refining each stage of the production process to reduce the cumulative negative impact of the production process on the environment. Dematerialization is intended either to reduce the use of raw materials and resources at the beginning and at each intermediate production stage or to find less pollutive alternative resource materials in order to ameliorate pollution generation and conserve resources.

5.2 Geographical Boundary

Identifying the geographical boundary of the eco-industrial park provides another context for analyzing it. At present, two categories of eco-industrial parks have been identified on the basis of the geographical boundary of waste exchanges: (a) among firms co-located in a defined eco-industrial park and (b)among local firms that are not co-located (meaning that industries could be organized "virtually") (Chertow2000). Other perspectives on geographical boundary for an eco-industrial park are presented below.

5.3 Development Model

Fleig outlines the developmental models foreco-industrial parks: exnihilo, anchor-tenant, business, stream, business-stream, and redevelopment, based on works of Ernest Lowe and Marian Chertow (Fleig2000,10). The list of six models however can be broadly categorized into two broad models, exnihilo and redevelopment, with others as variant sub-models:

- Exnihilo model: A new eco-industrial park is built on a fresh field with no pre-existing resources or networks.
- Redevelopment model: An eco-industrial park redevelops through analysis of material and energy flows, communication gaps, and possibilities of collaboration in a fully established industrial park so as to achieve enhanced environmental performance, cleaning up past pollution and presenting possibilities of improvement and facilitating communication and collaboration.

The business and stream models comprise the business-stream model. Likewise, the business-stream model and anchor-tenant model are components of the redevelopment model. In addition, Chertow advocated the green twinning and pre-existing organizational network models (Chertow 2000, 333).

- Greentwinning model: Identifying and implementing one exchange and then using it to spring board other exchanges.
- Pre-existing organizational network model:A network that can provide the initial platform for the inclusion of other industries and further networking possibilities.

5.4 Key Concerns and Empathies

Another way of looking at eco-industrial parks is based on key concerns. The key concerns of eco-industrial parks are related to technology, human community, and the biophysical environment. Predilection to one or the other concern explains the underlying approach as techno-centric, anthropo-centric,oreco-centric. The techno-centric approach focuses on technological improvement through process-level improvements. The eco-centric approach deals with the ecological improvements within the eco-industrial park site and the non-disruption of ecological flows beyond the site of theeco-industrial park. The anthropo-centric approach is concerned with socioeconomic benefits to the human community.

5.4.1 The Techno-centric Approach

Maximum efficiency in terms of inter-industrial exchanges is the key concern of this approach.Most of the inter-industrial exchanges occur in terms of materials and energy. These exchanges are strongly dependent on there usability of waste as a resource. Thus, end-of-life recyclability and disposability of materials with minimal damage to the environment are of paramount importance.

The consideration of an eco-industrial process begins with the identification, selection, and use of the recyclable materials at the start of the industrial manufacturing process (Manahan 1999). Improvement of the materials' cycle, reduction in waste generation, and low environmental impact are other important factors. Finally, the optimization of the materials' cycle from the beginning to end, with a focuson recognition and ramification of the pollutive process, influences the selection of less pollutive materials and cleaner processes (Soclow et al. 1994). The economics-based perspective influences the delineation of material flows that incur the least economic expense for the process level and end-of-the-line waste management. The extent of material flows and its impact on the environment with regard to economics and the optimization of material cyclesis a continuing inquiry subject of inquiry

The cause and effect of these associations involve demand and supply and ecosystem stability. Many other variables influence this relationship apart from the end-of-life properties of the material. For instance, the administrative, legal, economic, and environmental agendas are mooted by all industries that influence the relationship between the dependent and independent variables. For example, a raw material used by industry X might have a good end-of-life recycling potential in addition to being insufficient use able quantity for industry Y. However, the processing of the outgoing material from industry X in industry Y might pose an environmental and economic burden. Now if the administrative framework has not taken account of the distribution of this burden between X and Y industries, then the selection of the raw material might be vetoed by industry Y on the basis of environmental and economic liabilities manifested in resultant resource's output. Simultaneously, the independent variable depends upon developments in the fields of pure and applied science.

The environmentally sensitive approaches of selecting non-pollutive or the least pollutive raw materials, cleaner production processes and de-materialization are popular among many developers of eco-industrial parks. The Plattsburgh Eco-Industrial Park in Upstate New York, USA, for example, plans to network 3,500 neighboring areas containing research, commercial, recreational, and industrial facilities, with an emphasis on resource and waste management and lowered environmental costs and the objective of achieving compliance with ISO 14000/EMS umbrella program. The design of the East Shore Eco-Industrial Park in California, USA, takes into account the emerging trends towarda resource-efficient and renewable energy with an emphasis on energy efficiency, renewable energy and materials, and pollution prevention.

The major thrust in these examples is the stream lining of material flows and making improvements at the process level to achieve resource efficiency and waste minimization. Yet the delineation of the most economical and environment-friendly material flows and the attribution of monetary value to natural resources are still in the formativest ages and have yet to be translated into practice.

5.4.2 The Anthropo-centric Approach

For an eco-industrial park to exist as an accepted entity of the human community and perform efficiently, it needs to operate in tandem with a range of statutory and legal frameworks. The repercussions of the inclusion of eco-industrial parks within the residential precincts are being investigated. Korhonen (2001) highlight the increased opportunities created by the expansion of the exchanges from the site boundary of an eco-industrial parkt ot he regional scale in terms of a larger consumer market for the eco-industrial park and an employment base for the wider human community. Other benefits of industrial and human cohabitation are currently being investigated.

The human community residing in the vicinity of an eco-industrial park is influenced by the developments within that eco-industrial park. Any interaction between theeco-industrial park and the human community results in cumulative and important impacts. The positive impacts of this coexistence can be measured in employment and economic terms; however, the negative impacts that continue to persist are the hazards of land subsidence, floods or waterlogging, unhealthy biodiversity, depletion of resources, and disturbance of local ecological flows.

The literature reviews shows that interactions and exchanges of the eco-industrial park with the human community depend on the inclusion of community concerns since the planning stage, and impacts on the human community influence these interactions. Community involvement in stakeholder processes, the sociocultural fabric of the society, and the agenda of the local policy-planning body can have a significant impact on the cause-effect relationship. In short, advantages to the human community in terms of availability of consumer products, employment opportunities, and revenue are central to this approach.

The Green Institutein Minneapolis, USA, was basically initiated by the regional human community for the purpose of job creation, and both the eco-industrial park as well asthe human community measured the success of the project in terms of the number of jobs created. An initiative at Lingkungan Kecil Bugangan Baru Industrial Estate, Semarang, Indonesia, reflects a different dimension of collaboration between the eco-industrial park and the human community by providing culturally sensitive buildings, such as a mosque, as shared infrastructure and by facilitating the salability of the manufactured products by providing a common showroom. At Naroda Industrial Estate, Ahmedabad, India, the eco-industrial park added a hospital, canteen, post office, banks, and a police station in addition to sharing basic infrastructure services such as roads, water, power, and communications facilities with its community.

5.4.3 The Eco-centric Approach

Interactions between the component organism and the ecosystem contribute to the stability of the component as well as to the composite natural ecosystem. This ecological concept forms the inspirational cornerstone of an eco-industrial park with respect to its ecosystem and leads to a paradigm shift.Developing the eco-industrial park as an ecosystem made up of eco-subsystems on one level and as a part of the macro ecosystem on another level and developing the eco-industrial park as a system that causes no disturbance or the least disturbance to the ecosystem (Soclow et al.1994; Manahan 1999) formulate the predominant concerns of the eco-centric approach.

Eco-sensitive measures such as protecting sensitive ecosystems, restoring natural resources, constructing stormwater retention ponds, and limiting the amount of impermeable surfaces are already being implemented by ecologically conscious eco-industrial parks. The East Shore Eco-Industrial Park in Oakland, California (USA), has landscaped its site with native vegetation, and Cape Charles Sustainable Technology Park in Virginia (USA) collects storm water run off in a constructed wetland that improves the ecological and aesthetic value of the eco-industrial park while setting aside 25 of the 50 acres of existing wet lands for preservation. The Riverside Eco-Park is an agricultural-industrial park in an urban setting, which uses engineered vegetation and related products to generate electricity that is channeled into the commercial greenhouse production of fish and organic vegetables and water purification. Other eco-industrial parks such as Shady Side Eco-Industrial Park, Maryland, USA, attempt to attract ecologically friendly industries such as water reclamation, solar and renewable energy, composting, or fish and shellfish aquaculture as the primary or secondary industry. Environmental management within Naroda Industrial Estate, Ahmedabad, India, has created its own land fill for hazardous solid wastes and has set up a common effluent treatment plant to improve the efficiency of waste water treatment within the estate.

5.4.4 Transformation of Industrial Park to Eco-Industrial Park through History

Here is a summary of keys industrial parks that played a role of a key exemplar in establishment and transformation of an industrial park to eco-industrial park:

- **1890s: Europe**
  - The first industrial estate was planned in Manchester, England, when a private company, Trafford Park Estates Ltd., purchased a 1,200-acrecountry estate on the Manchester Ship Channel adjoining the docks. This industrial district was dominated by heavy manufacturing (ULI, 1988).
- **Early 1900s: North America**
  - The Original East District and the Pershing Road District were established in 1902 and 1916, respectively (ULI 1988). By the 1950s, larger industrial estates were being planned and developed in the United States and Canada.
- **Late 1900s: Europe**
  - Europe adopted the concept of industrial parks specialized by function. Sophia Antipolis, the international business park near Nice in France, was developed in the 1970s (ULI 1988).
  - Cambridge also developed as a high-tech center in the 1970s and 1980s (Castells et al. 1994).

  - The 1970s and 1980s saw the gradual removal of heavy manufacturing industries from industrial parks. Bias toward knowledge and research-intensive development was imminent.

- 1980s: Asia-Pacific/Australia
  - The 1980s saw the development of industrial/research parks in Tsukuba, Japan. Many more were planned through the years, with a focus on Sendai HokubuResearch and Industrial Park and Izumi Parktown Industrial Park, completed in the year 2000. HsinchuScience and Industrial Park was planned and established by the national government of Taiwanand started operating in 1980. It includes industrial, residential, and research zones. China, Malaysia, and Indonesia also witnessed the development of science and technology–related industrial parks through the 1980s.
  - Technology Park Adelaide was established in 1983 in Adelaide, Australia (Castells et al. 1994).

- 2000s: Developing Countries
  - Growth in manufacturing is higher than in agriculture (Szirmai 2012,413). Urbanization and industrialization arepredicted estimated to expand in developing countries, and understanding the relationship with energy consumption will be an important research area through the coming years (Sadorsky 2013, 58).

6. Conclusion: Conditions That Act as Catalysts for Industrial Transformation

The study shows the close interrelationship between the industrial park and eco-industrial park. Basically, the industrial park has evolved into the eco-industrial park at an operational level, performing more efficiently. The efficiency level here was defined as sound economic benefits with the least negative impacts on the immediate natural and social environment. The exploitation of the concept of sharing infrastructure and the perspective regarding conservation of resources, which were absent in the industrial park, was a sound economic, systemic, and intellectual innovation achieved by the eco-industrial park.

The objectives of an eco-industrial park reflect a filial connection with the industrial park. Through the above discussion, the common objective can be identified as "collective benefit due to mutual matter and energy exchanges with minimum negative impacts on the human and natural environment." The issues governing the evolution of an industrial park and eco-industrial park have been similar. Broadly, the issues can be categorized as economic, social, political, ecological, and intellectual. It is difficult to establish the hierarchy of issues according to their influential capacity on the situation that generated the concepts of theindustrial park and eco-industrial park. The influence of these issues varies with the time period. A range of perspectives—viz., economics and politics—had a major influence on the development of the industrial park, whereas ecological, political, and economic issues affected the development of the eco-industrial park.

A critical review of literature, case studies and a field study in Kalundborg, projects the catalysts for industrial transformation as: environmental (impacting people), ecological (impacting the ecosystems and humans that are a part of it), political (related to social and environmental accountability), and economic (as an underscore to all other aspects).

Notes

1. A business park is a conglomeration of non-pollutive light manufacturing industries and high-technology research-oriented businesses.
2. A science and technology park houses"research and development" and knowledge-intensive setups focused on training scientific and technical brains.[1]
3. The NIZC was a nonprofit group composed of delegate committees from eight nationwide organizations—viz., American Society of Planning Officials, American Industrial Development Council, American Institute of Planners, American Railway Development Association, American Society of Civil Engineers, Industrial Development Research Council, Society of Industrial Realtors, and Urban Land Institute.

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