ABSTRACT

Title of Document: A DECISION-BASED DESIGN PROCESS FOR ECO-INDUSTRIAL PARKS

Time O. Aigbe, Master of Science, May 2011

Directed By: Dr. Jeffrey Herrmann, Mechanical Engineering and Institute for Systems Research

This thesis presents a new process for designing eco-industrial parks (i.e., EIPs) that identifies the decisions that need to be made during each phase. A literature review about the different EIP development processes in the U.S. and worldwide is conducted to create a general EIP development process. A careful analysis of 21 EIP development processes was conducted to illuminate the different routines associated with each step in these processes. This thesis presents a revised EIP development process that follows the decision-based design principle of aligning all decisions with the involved organizations' most important objectives.

A DECISION-BASED DESIGN PROCESS FOR ECO-INDUSTRIAL PARKS

By

Time O. Aigbe

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Science
2011

Advisory Committee:
Associate Professor Jeffrey W. Herrmann, Chair
Associate Professor Linda C. Schmidt
Professor Reinhard K. Radermacher

Acknowledgements

I would like to thank a number of people for making the completion of this Thesis possible. I would like to thank my graduate advisor: Dr. Jeffrey W. Herrmann, for making himself available for consultation on a frequent basis, for providing technical support on the nature of engineering decision making and much more. I would like to thank my family for encouraging me to continue on to graduate study and playing a much needed supporting role outside of school. I would like to thank my Thesis Committee members for taking the time out of their busy schedules to read and review my thesis, as well as participating in my Thesis Defense. I would like to thank the professors of the graduate courses I participated in for helping me build the knowledge base necessary to conduct research and compose this thesis. I would like to thank the Sustainable South Bronx and Green Worker Cooperatives for providing me with the technical and non-technical information needed to produce an example from South Bronx's Oak Point Eco-Industrial Park. Lastly, I would like to thank the Bridge to the Doctorate Fellowship Program for providing me with funding and the opportunity to partake in guided, independent research of my choosing.

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1.1 –Sustainability

1.1.1 – Sustainable Development

Current economic trends and industrial production methods focus on maximization of two quantities: the value added to customers and corporate profits. These principles have led to industrial systems that extract renewable and non-renewable resources for feedstock and eject the production process's waste into landfills and other terminal waste disposal areas (decreasing the Earth's carrying capacity). Some industries (both within the United States and around the world) fail to replenish these renewable resources at a rate faster than they consume them (Spriggs et al., 2004). Even though this strategy has propelled the United States into such a prominent economic position in the world, it fails to address how we, as human beings, intend to ensure that future generations will have the renewable (and non-renewable) resources that we enjoy today (Gertler, 1995). To combat this dilemma, a new goal for industrial system developers has come into focus: sustainability. Many definitions exist for the word "sustainability," but Reap (2004) provides an effective definition that encompasses the foundation and goals of sustainability:

> “Sustainability (a working definition) – a persistent state of a coupled ecological and economic system that preserves biotic integrity and stability while simultaneously allowing human inhabitants [both current and future] “to be well off.”

In essence, employing sustainable principles would lead developers of industrial systems to design systems that require fewer resources for production processes and reduce the amount of waste being (1) produced and (2) diverted to landfills and other waste disposal sites. Because considering the goal of sustainability is applicable to all countries, it is no surprise that it has caught the attention of the United Nations. In 1987, the World Commission on Environment and Development (WCED) (an entity of the United Nations) met at the World Environment and Development Conference and defined sustainable development as (WCED, 1987):

> ‘‘. . . [a] development seeking to meet the need of the present generation without compromising the ability of future generations to meet their own needs. It aims at assuring the ongoing productivity of exploitable natural resources and conserving all species of fauna and flora.’’

Following this definition, a number of socio-environmental directives were established and adopted by the participating countries. These directives called for the adoption of sustainable development principles in the form of political and management strategies that focus on balancing social equity, environmental integrity, and economic efficiency (Rosenthal et al., 2003). A useful Venn diagram can be seen in Figure 1.

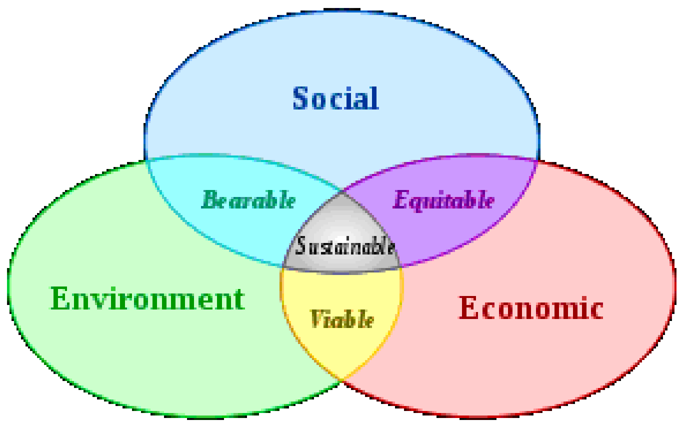


Figure 1: Scheme of sustainable development – three components of a typical ecology and four beneficial intersections (sustainability being the ultimate goal) (UCN, 2006)

Figure 1 demonstrates beneficial results from relationships between society, the economy (i.e. financial well being of stakeholders and decision-makers), and the environment. When careful planning and design of industrial (and other consumptive) systems are implemented, viable, bearable, and equitable solutions create two-way positive relationships between their respective entities (i.e. overlap between just two global entities). Ideally, when planning and design of industrial (and other) systems are executed with all three entities in full consideration, a three-way intersection is met, and a sustainable system is born. While ensuring the feasibility of the project, industrial systems should be designed with sustainability being a top goal.

Efforts to attain sustainable development can be seen through the creation of the ISO14000 series in 1996 (*ISO 14000 / ISO 14001 Environmental Management Standard*) by the International Organization for Standardization (ISO). As proof of its popularity, by 2008, this set of standards was adopted globally by over 130,000 organizations worldwide (Nawroka and Parker, 2008). ISO14000 is a series of international standards on environmental management that provides a framework for the development of an environmental management system (EMS) and the supporting audit program. The cornerstone standard of the 16 standard series is ISO14001. This standard is a framework for companies looking to set up their own EMS so they can achieve their economic and environmental goals. According to ISO, an EMS is:

> ". . . part of the overall management system, that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving and maintaining the environmental policy"

In addition, ISO14001 uses the Plan-Do-Check-Act methodology to ensure that economic and environmental performance is improving from year to year (Federal Facilities Council Report, 1999). In theory, this series of standards seems to improve the sustainability of industrial system developers who choose to cooperate with it. However, there are some weaknesses associated with ISO14000. One conference held by the EPA in 1996, and documented in McCloskey (1996), illuminates a few of these problems:

- "It is quite unclear as to how much bad performance can slip through the process-oriented net of ISO 14000. Systems could be set up with poor goals and commitments could be disregarded. Audits could reflect this under-achievement (since companies are registered), but would there be any ISO violation?

- ISO cannot be credible if rogue companies can misuse it. Will the currency be debased, particularly in developing countries? When large sums of money are at stake, which company member will stand firm to make sure that ISO does not become a refuge for poor performers?
- Firms can become certified simply by self-declaration; they do not have to go through a third party registrar. How can consumers place any faith in claims which are not independently verified?
- The same problem also applies to auditing. Firms are not obliged to use qualified third parties to audit their operations. They can audit themselves. How much credibility will these have?
- Moreover, firms are not required to make the results of their audits public. Nor do they have to make most of their ISO required documents public. What kind of accountability is that?
- In fact, there is a basic question about the legitimacy of ISO 14000 standards themselves since they have come out of a process which has not been open and inclusive. Key stakeholders were not involved at formative stages. Basically this was a self-regulation process run by transnational corporations in the first world. There is no semblance of democratic account-ability about it."

With all these problems inherent in the ISO 14000 series, industrial ecology must gain popularity in the minds of decision-makers and, following implementation, be effectively measured by EMS's worldwide.

1.1.2 – Triple Bottom Line

The triple bottom line can best be described as a corporate performance measurement standard within the context of sustainable development. It can be thought of as a multi-objective optimization problem that implicitly sets the "…simultaneous pursuit of economic prosperity, environmental quality and social equity" as goals for every company (Elkington, 1998). The metrics used to measure value for each particular entity are not always obvious; money flow fluctuations can divulge economic impact, but it is up to the company in question to determine suitable societal and environmental measures of effectiveness. This can be done by looking at the physical effects on the environment (like waste disposal rate, or resource consumption rate); however, there is some difficulty in determining the boundary of the industrial system and its respective effluents and needed feedstock. Life cycle analysis could be conducted to determine how a particular company is impacting its surroundings. Societal benefits and impacts can be measured by considering the stakeholders (people in the surrounding communities, business communities and others directly or indirectly affected by the industrial system in question). An increase in tax base to the region, newly created high-skill level jobs, increase in traffic to complementary industries, re-growth of renewable resources (or revived public property), decreases in utilization of local landfills, and similar measures can all be considered as useful indicators for increasing social equity (Gertler, 1995).

1.2 – Industrial Ecology

1.2.1 – Principles and Purpose of Industrial Ecology

Industrial ecology is the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the use, transformation, and disposition of resources (White, 1994). Through the comparison of material and energy flows, industrial entities (factories, industrial parks, industrial networks, etc.), consumer markets, and waste management services are modeled as organisms that exist in nature. These entities possess industrial metabolisms (i.e., an intake of needed substances and subsequent discharge of waste substances) and inter-entity relationships that mimic their organic analogies. Figure 2 illustrates the comparison between the players involved in a natural ecosystem and an industrial ecosystem.

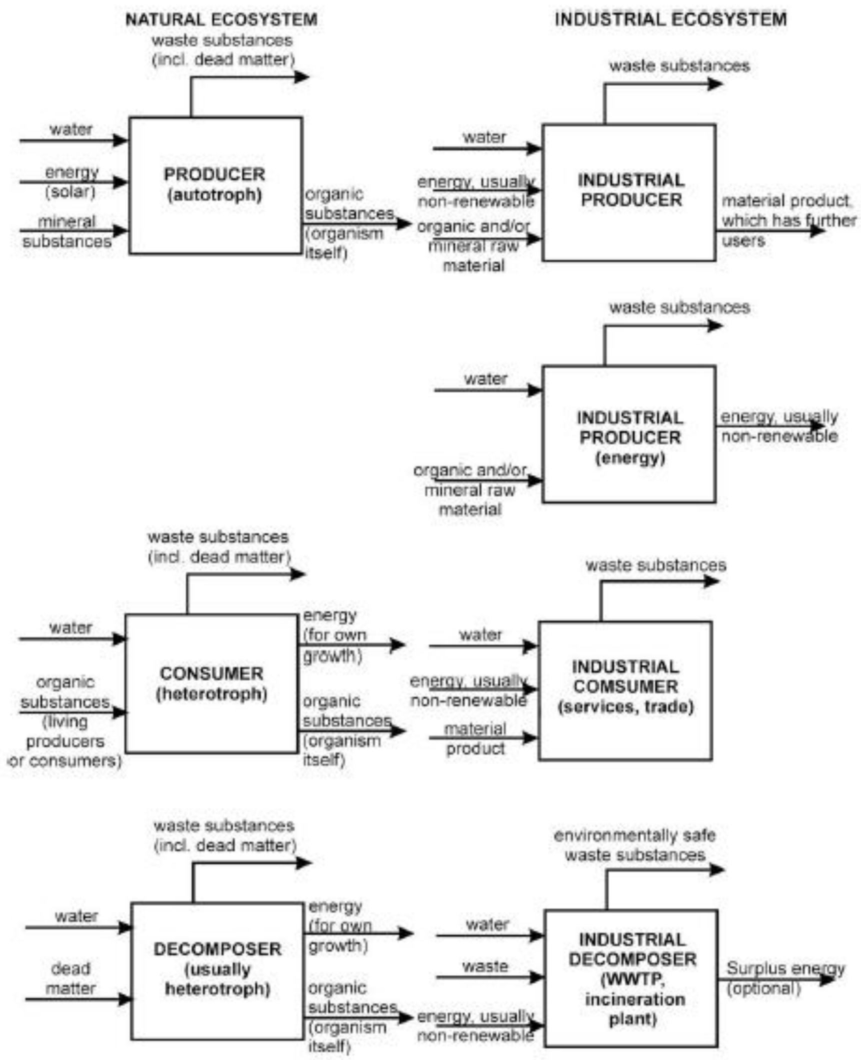


Figure 2: Comparison of the Actors and Activities within Natural Ecosystems (left) and Industrial Ecosystems (right) (Côté et al., 1994)

This concept was first discussed by Frosch and Gallopoulos (1989). The primary goal of industrial ecology focuses on transformation from a linear, wasteful economy to a closed-loop system of production and consumption. In such a system industrial, governmental, and consumer discards would be reused, recycled, and remanufactured at the highest values possible (Lowe et al., 1997).

In addition, industrial ecology is scalable. That is, it can be applied to a single industrial park or an entire region of a country or state, but it ultimately relies on the availability of information (see Figure 3). This information can be used in conjunction with material and energy balance to analyze the positive and negative impacts that well-defined ecological systems, or scaled-industrial unit operations, may have on the surrounding environment and communities (Diwekar, 2005). Figure 4 graphically demonstrates the different scales of industrial ecology (and eco-industrial development for that matter). At the lowest level, a manufacturing firm (i.e., "factory") conducts its operations and requires input resources to transform into useful output products. These inputs can be gathered from neighboring factories (within the eco-industrial park) or firms within the regional eco-industrial network. Simultaneously, the factory's marketable output can be sold to anyone in demand, while the undesirable output (e.g. waste, hazardous material, excess heat generated, grey water, etc.) can be reprocessed and sold or given away to participants within industrial ecology.

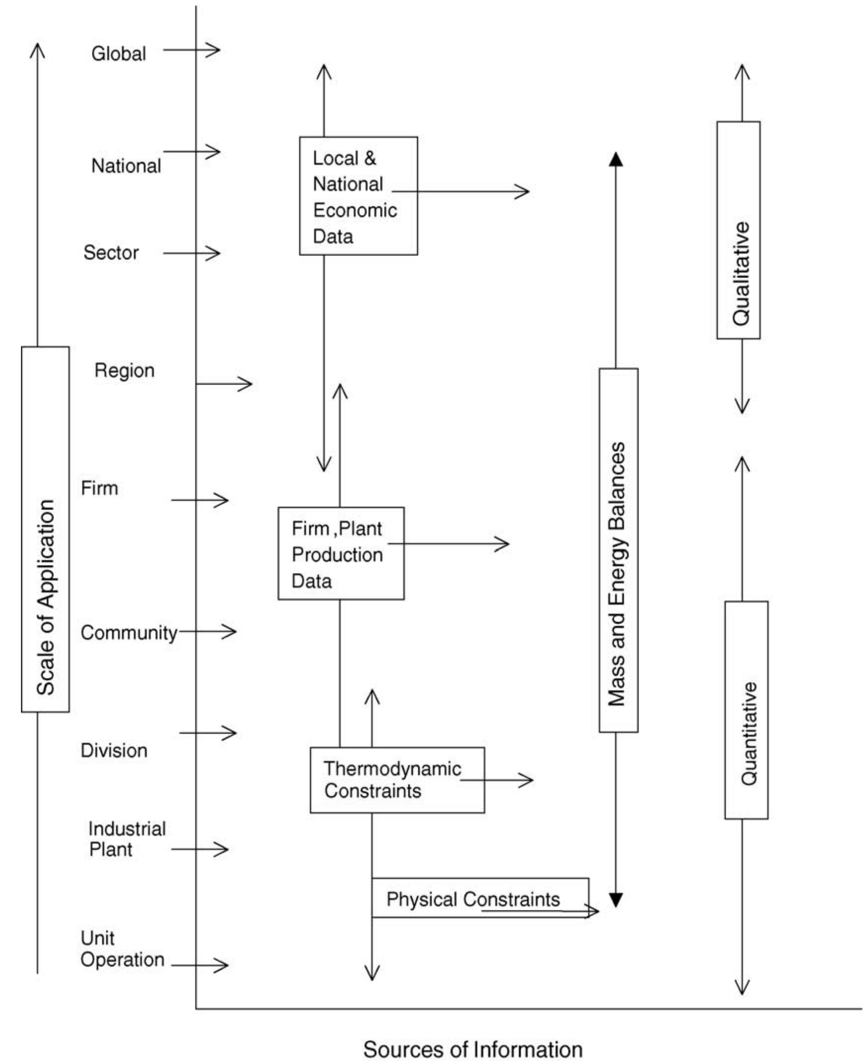


Figure 3: Scalability of Industrial Ecology with respect to known Information (Diwekar and Small, 2002)

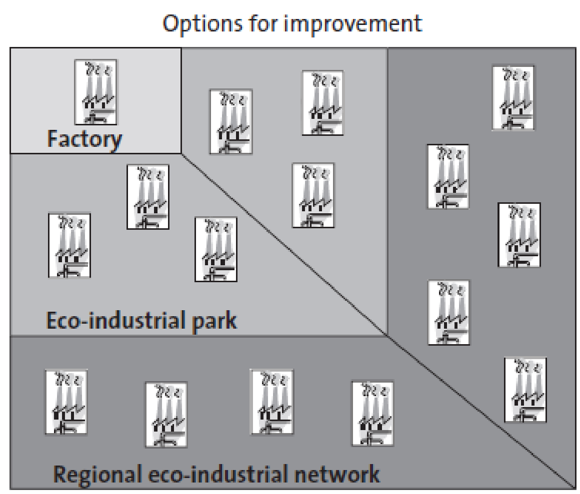


Figure 4: The Multi-scale depiction of Industrial Ecology (Cohen-Rosenthal and Musnikow, 2003)

The overarching purpose of industrial ecology is to unite the requirements of industrial and natural systems and determine how the industrial system can achieve higher efficiencies (at lower cost if possible) and lower pollution rates (e.g., closed loop production systems). This is done by mimicking the natural ecology model. For example, in nature, every waste is used by some other organism within the ecosystem. In an industrial ecology model, this means that first a business minimizes its resource usage; any remaining waste is used as a resource by another business within the system. Waste (energy or material) is diverted from landfills and other terminating locations that do harm to the environment and nearby communities. This diversion leads to the utilization of wastes as reusable feed-stock material (or an energy source) by another industrial system (Nolan, 2004). In the end, industrial ecology is the study of material and energy flows with its most important application being in the realm of eco-industrial development. "The ultimate goal of industrial ecology is to reuse, repair, recover, remanufacture, or recycle products and byproducts on a very large scale (Desrochers, 2001)."

1.2.2 – Eco-Industrial Development as an Application of Industrial Ecology

Eco-industrial development is a term describing the process used to analyze, design, and develop an industrial ecosystem. Eco-industrial developments apply the concepts of industrial ecology through implementation of industrial symbiosis. The term "symbiosis" designates relationships within nature where at least two otherwise unrelated species exchange materials, energy or information in a manner that results in synergies (i.e., benefits through a combined and complementary effort) for all involved parties (Veiga and Magrini, 2009). In the context of industrial systems, an eco-industrial development would try to match companies that have the proven capability to exercise industrial symbiosis between one another. The industrial symbiosis between the industrial system's participants would be an exchange of by-products (from production processes), information (to find new by-product or energy exchanges), or energy (i.e. waste heat, steam, or heated water that is normally disposed of) that is not readily available. The recycling and reuse of materials, water, and energy are the means by which eco-industrial development, where applied correctly, attempts to reach its goal of a more beneficial triple bottom line. In the United States, the President's Council on Sustainable Development (PCSD) began in June of 1993 to encourage the establishment of demonstration sites (i.e. projects intended to become eco-industrial parks or networks). To make the effort more concrete, the National Center for Eco-Industrial Development was established as a research and information center at the University of Southern California, funded by the U.S. Department of Commerce's Economic Development Administration, the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. The council was disbanded in June, 1999 (Gibz and Deutz, 2004).

1.3 – Eco-Industrial Parks

In the literature on this topic, many authors have defined what an eco-industrial park (EIP) is. However, it may be helpful to first remove any common misconceptions of what an EIP is supposed to be. Lowe (2001) presents several characteristics of industrial parks that seem surprisingly close to elements employed by actual EIPs:

“To be a real [EIP,] a development must be more than:

- A single by-product exchange or network of exchanges;
- A recycling business cluster;
- A collection of environmental technology;
- A collection of companies making ‘green’ products;
- An industrial park designed around a single environmental theme (i.e., a solar energy driven park);
- A park with environmentally friendly infrastructure or construction;
- A mixed-use development (industrial, commercial, and residential).”

Although Lowe (2001) presents solid examples of implementation strategies that an EIP may exercise, if any one characteristic is employed *alone*, the result is not necessarily an EIP. Recall the purpose of eco-industrial development is to help the region in question (i.e., business community, residential community, surrounding environment, and park tenants) achieve the triple bottom line. Each of these characteristics can contribute to portions of the triple bottom line improving. For example, a collection of companies making “green” products would benefit society and the environment in the long run by making environmentally friendly products that meet the demands of society. However, the “green producers” would not necessarily see a large economic benefit. Like traditional industrial park arrangements, the economies of scope that are associated with the co-location of a collection of companies making “green” products includes shared common resources (i.e., water, energy, some common feedstock, etc.), shared services that are complementary to operations (i.e., waste management services, medical services, cafeteria services, etc.), and shared common infrastructure (i.e., roads, parking lots, telephone lines, internet access, warehouses, etc.) (Cohen-Rosenthal and Musnikow, 2003). However, the interactions between the tenants and the surrounding community are not enhanced if the concept of multiple by-product exchanges (and the associated benefits) is not implemented to the fullest.

Now that it is clear what an EIP is not, PCSD (1996) presents a sensible definition of what they are:

> "[An EIP is] a community of businesses that co-operate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure, and natural habitat), leading to economic gains, gains in environmental quality and equitable enhancement of human resources for the business and local community."

It is important to realize that this definition highlights two important principles of an EIP: (1) co-operation between the tenants and the local community in the form of sharing and (2) the utilization of the triple bottom line approach. If either of these principles is not implemented in practice, then the industrial entity in question is not an example of eco-industrial development.

Eco-industrial developments are typically centered on a "theme" that takes full advantage of the resources available to the region in question. This organization is typically deemed the "anchor facility" (or just "anchor") of the EIP. The anchor typically has a symbiotic linkage with a majority or all of the tenants within the EIP. It is important to realize that the byproducts required and produced by the anchor serve as attracting mechanisms that draw potential tenants into the EIP. Additionally, new byproduct exchanges can develop from exchanges exclusively between the anchor and each tenant to exchanges between ordinary tenants—which is ideal (Lowe et al., 1997). A hypothetical EIP can be seen in Figure 5 . It demonstrates a number of real, potential linkages involving popular byproducts that—assuming compatible local regulations, industry presence, and technological capability—can be implemented by an anchor and the EIP tenants associated with the industrial sectors shown. Within the appendix, Table 40 provides a more in-depth description of the more popular industrial clusters and the byproducts associated with them.

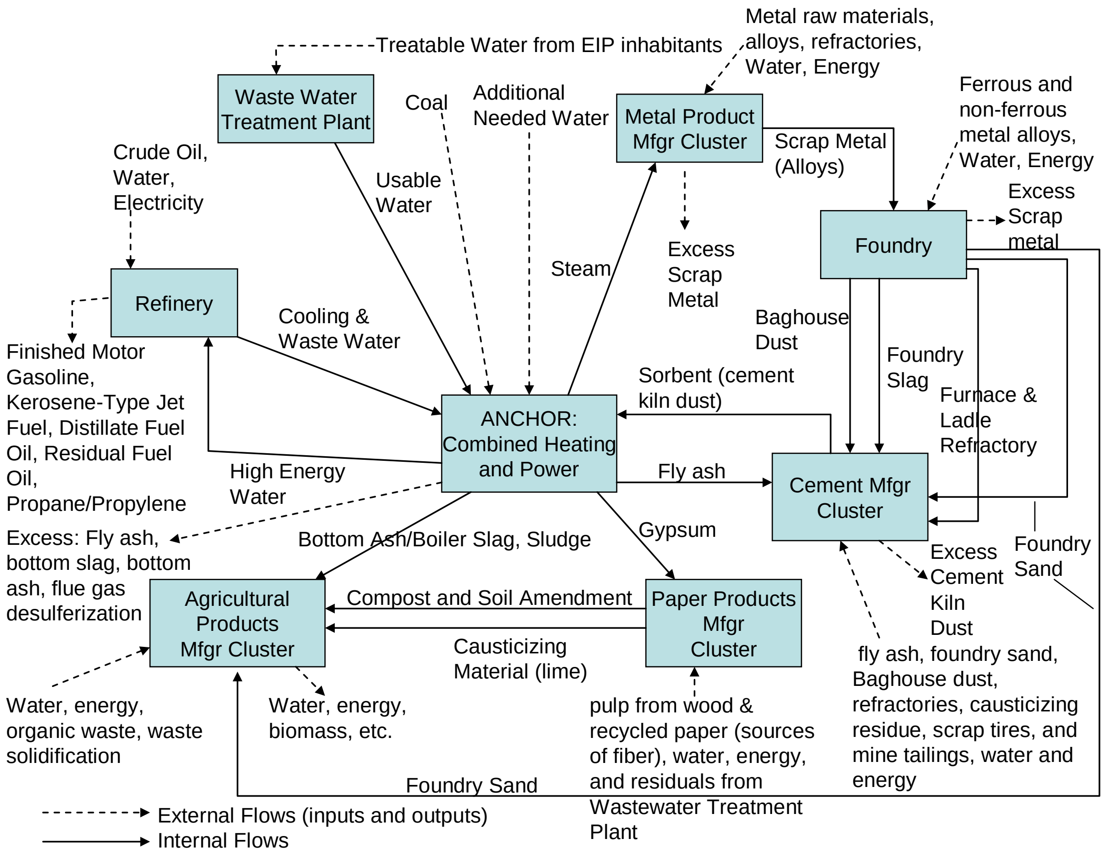


Figure 5: Hypothetical Linkages between EIP Tenants and Anchor Facility

1.3.1 – Vision and Goal of Eco-Industrial Parks: How they Ensure Sustainable Development

The vision statement of an EIP is responsible for portraying what the EIP decision-makers and stakeholders consider their purpose and guiding beliefs for how things should be done. Through an effective vision statement, the sustainable development objectives can be made clear. Advertising the vision of the EIP to potential tenants makes it clear what they should strive for in order to be deemed a benefit to the EIP (Lowe et al., 1997). North and Giannini-Spohn (1999) list several exemplary vision statements that are associated with existing EIPs:

- Physically connect businesses into a network, with a goal of zero emissions;

- Restrict park to companies that generate no pollution or environmental technology firms;
- Restrict park to companies with environmental management systems in place and with excellent regulatory histories;
- Focus on park infrastructure, with energy-saving “green” buildings, buildings designed for re-use, recycled or deconstructed buildings, and xeriscaping (landscaping for maximum water conservation).

The goal of an EIP is aligned with the goal to sustainably develop a given region. This means improvement of economic performance by participating companies, improvement of social equity (i.e., added benefit to neighboring community), and the minimization of environmental impacts. Design elements of eco-industrial parks include green design of park infrastructure and facilities (new or retrofitted); cleaner production; pollution prevention; energy efficiency; and intercompany partnering/sharing (e.g. symbiotic exchanges of materials, energy, and water) (Lowe, 2001). According to Dunn (1995), EIPs should contain the following elements:

- Industry match: in terms of inputs and outputs.
- Size match: companies should be of comparable size in terms of their material exchanges.
- This reduces the need to send materials to a party offsite, minimizing transaction costs and improving efficiency.

- Close physical distance between firms: close physical distance minimizes loss of materials in exchange processes, reduces transportation needs and costs, and reduces operating costs.
- Close proximity facilitates communication and information exchange among management and employees, resulting in more secure partnerships.

1.3.2 – Road Blocks to Eco-Industrial Development

Eco-Industrial Park development is a complex, multi-disciplinary project that one should expect would be accompanied with its own set of "road blocks." These "road blocks" make it more difficult to establish an eco-industrial park, and their influence should be considered realistically through a feasibility study of the region in question prior to getting deeply involved (especially monetarily) with an EIP development project. When considering the human component of sustainable development and EIP projects, the complexity arises with such a large number of different decision-makers and stakeholders (crossing multiple organizations; each with their own respective intentions). The wide array of preferences held by decision makers and stakeholders can make maintaining consensus, information flow, and overall project organization quite challenging. More generally, Spriggs et al. (2004) categorizes the spectrum of challenges into two types: technical/economic and organizational/commercial/political.

The technical/economic challenge is "how to integrate mass and energy flows economically – both locally within a processing unit and globally among many processing units and even companies" (Spriggs et al., 2004). Unlike conventional industrial parks or business clusters, EIP designs must promote by-product exchange and have a cost-effective way of doing so. The integration of intermediate material, product, and byproduct flows must be established between tenants and the surrounding community. This integration, in addition to physical-infrastructural connections, must be carried out in a manner that will not scare tenants away (via high upfront "move-in" costs), or impose a too-large burden on government and investor funding. In other words, the EIP concept must achieve mass and energy balance and the symbiotic linkages must prove economically beneficial for all tenants involved (Spriggs et al., 2004). Other factors adding difficulty to eco-industrial development include the high transaction cost associated with working with the community and other businesses (especially competitors), in terms of time, labor, transportation, labor, recovery and exchange infrastructure, communication, and monitoring (Pelletiere, 1999). Since each byproduct is responsible for creating a new market, it will be challenging to assess the value of these byproducts in an equitable manner; tenants need to be compensated for the byproducts they offer other tenants and community members, however, these byproducts must not be more expensive than conventional sources of the underlying feedstock or energy source that the byproduct is replacing.

Spriggs et al. (2004) emphasizes the organizational/commercial/political challenges associated with creating a byproduct exchange by bringing up the following issues:

- What level of integration should be promoted among individual companies?
- Who owns what production units?

- Who owns the infrastructure?
- What are the commercial arrangements among the integrated parties?
- What are the regulatory and legal obstacles to this type of integration and what types of changes are required to provide incentives for greater integration (for example, tax subsidies)?

Even though these questions can be answered by the participating decision-makers, the answers cannot be generated with full certainty; constant change in a dynamic business climate, changing market trends, and evolving government regulations make these questions more difficult to answer. The challenge faced by EIP tenants involves having business models that are flexible and agile enough to cope with supply-side and market changes (Spriggs et al., 2004). In addition, since EIPs are designed with respect to the region they reside in, it is not possible to simply mimic another country or region's EIP development methodology. Resource availability, industrial presence, community product and service demands, renewable energy feasibility, and many more factors are heavily reliant on the geography and the social identity of the proposed region.

Accounting for the number of existing eco-industrial projects with very few years of operational experience, and the fact that many eco-industrial parks never survive infancy, makes it clear that there are a set of real and perceived uncertainties and risks associated with the design and development of eco-industrial parks. In addition to the challenges associated with eco-industrial development, it is also important to consider the risks. The first risk that developers must consider is financial. The lack of proven successes on which to assess risk and a potentially longer payback period may cause the financial community to be reluctant to support eco-industrial development projects (North and Giannini-Spohn, 1999). In addition, materials exchange agreements (involving tenants and possibly even external businesses) that outline the trade of recovered byproducts (e.g., prices and guaranteed quantities of materials, energy and water) will gain approval only if the recovered - and, if necessary, reprocessed - byproducts cost less than either their disposal cost or the price of comparable virgin materials. Secondly, the material and energy interdependence between neighboring tenants (and even between the park and the community) is a real risk (Pelletiere, 1999). The quantity and quality of byproduct supply can only be estimated because there is a degree of uncertainty (with respect to shifts in production) that is a function of market demands (Schlarb, 2001). Once infrastructure and additional processes to facilitate a byproduct exchange between two or more firms have been fully developed, these firms will not want to relocate or innovate. Relocation of a firm out of the EIP will nullify the money invested in infrastructure and additional processes. Innovation is at risk, because firms will not want to change the materials they use or the production processes they employ in order to maintain byproduct exchange agreements and the cost savings associated with them (Lowe, 2001). If EIP firms innovate only with respect to byproduct exchange, then these efforts may yield high cost savings on materials, production process steps, or needed personnel. However, this switch in innovation direction can prevent breakthroughs (in terms of time and money) in cleaner production and pollution prevention methods that may be more beneficial than the byproduct exchange for the environment; thus, the environmental bottom line is at risk. Thirdly, EIP developers must identify the risks of liability or confusion over definitions of hazardous wastes. The Resource Conservation and Recovery Act (RCRA), for example, limits handling and use (or, in this case, reuse) of some hazardous waste materials. In fact, about 1/3 of industrial byproducts have been given the "hazardous label" (Gertler, 1995).This can deters businesses from entering into a materials exchange agreement, because one firm's chief output material may be on the RCRA's list of hazardous waste materials, which bars the firm from selling its byproducts to neighboring tenants and the surrounding community (Schlarb, 2001).

1.3.3 – EIP borne Benefits to Community, Inhabitants, and Environment

Eco-Industrial Parks are beneficial to the communities surrounding them because the interests of the firms within the park become aligned with the interests of the community and the environment. As mentioned earlier, this alignment is typically reflected in the goals of each eco-industrial park project. In order for the firms within the park to benefit most (with respect to profit margins and an eco-friendly reputation), they must perform operations that add value to waste byproducts generated by the park inhabitants and the community, and transform them into marketable outputs (in the form of a service or product). The benefits extend to others besides the EIP tenants, which is the source of their added benefit. Positive externalities ensue from a successful EIP, and the community shows its appreciation for the EIP by buying its marketable products, or providing the EIP with a qualified work force. The environment appreciates the EIP and continues to regenerate renewable resources for the EIP.

Benefits to EIP Tenants

The tenants of the EIP receive the benefit of economic efficiency and profitability. Economic efficiency is realized in the sale and purchase of byproducts, sharing the burden of expenses for infrastructure and services, and improvements in reputation as an eco-friendly organization.

The byproducts that each firm purchases are only beneficial if all costs associated with that byproduct (e.g., the cost of the byproduct from the provider; the cost to reprocess, remanufacture, or transform the byproduct into a usable or marketable condition; the cost to transport the byproduct from its source; and other costs) are less than the cost of purchasing and transporting a substitute material from conventional suppliers. In addition, the resale of waste translates to the elimination of disposal fees that would be imposed on what used to be waste (Schlarb, 2001). So essentially, a liability has been converted into an asset.

Common to tenants of industrial parks, eco-industrial park tenants would see benefits from shared infrastructure and services. These include business services (like cafeteria staff), waste management, purchasing, training and recruitment, recreation and childcare facilities, transportation (e.g., shuttle service), and other common costs of doing business (Schlarb, 2001). The co-location would also benefit firms that are exchanging byproducts by reducing the amount of energy spent gathering and transporting resources, since the source of these resources is within the park itself. Lastly, tenants may see a decrease in some research and development costs (Lowe et al., 1997). For example, if firm A has a byproduct that has reuse potential (i.e. ability to be used as a feedstock, energy source, etc.) in the eyes of firms B and C, then firms B and C may collaborate on the research pertaining to restoration of firm A's byproduct. Sharing infrastructure and services certainly adds benefit to the tenants, which explains why conventional industrial parks flourish today.

Benefits to Community

The EIP impacts the community in a number of ways. The first benefit observed by the community is an increase in higher paying, high-skill level jobs and businesses. Although the tenants typically do not move their corporate offices to the EIP, they will be looking to fill positions for manufacturing/production technicians, management, engineers, and a whole host of other occupations that the firm in question needs to run its business locally. In fact, the Green Institute in Minneapolis, Minnesota, and the Cape Charles Sustainable Technology Park in Cape Charles, Virginia, provide incentives to tenants within the EIP who hire local workers (Schlarb, 2001). As the employment rate increases, the community also sees an increase in the standard of living and a higher tax base (which can be reinvested in the community and lead to additional benefits). Along with new jobs within the EIP, new businesses may be created inside and outside of the EIP to take advantage of, or even help facilitate, byproduct exchanges. These third-party businesses (e.g., recycling centers and waste water treatment facilities) are called upon to reprocess a byproduct for utilization by another firm or the community (Schlarb, 2001).

The second benefit observed by the community is overall community development. In fact, "many eco-industrial park projects have incorporated incentives for training and hiring minorities and women, salary improvement programs, and family-friendly policies" that add benefit to individuals within the community directly (Schlarb, 2001). Similarly, cleaner air, cleaner water, and an "emphasis on green design [capable of improving] indoor workspace quality, [results in improved] worker health and productivity" (Lowe et al., 1997). If the local EIP contains a low-cost power (or renewable energy) generation company, then the next direct benefit observed by the community would be a collective decrease in their electricity bill. This is assuming the power generation company is purchasing unwanted byproducts at bargain prices (i.e. prices lower than the cost of coal) and reprocessing them to produce power, cascading energy from another firm's nearby high-energy production process, or simply utilizing a renewable energy source (Lowe et al., 1997).

Lastly, the incorporation of an EIP would benefit the community by increasing the gross regional domestic product (GRDP). An increase in the GRDP usually leads to an increase in the average standard of living, but this increase in the standard of living is not uniform throughout the community. Either way, the increased GRDP would consequently increase the tax base of the region in question. These additional taxes are in the control of the government, but reinvestment of these tax revenues can benefit the community through improved community infrastructure (e.g., more street lamps, better roads, sidewalks, etc.), improvement of community development programs, or increased spending on programs and projects that will benefit the community directly (or indirectly). In general, if the EIP is operating within safety regulations, then the community will see an increase in their society's bottom line.

Benefits to Environment

Considering the ultimate goal of EIP strategy is to "reduce the use of virgin materials, decrease pollution, increase energy efficiency, reduce water use, and decrease the volume of waste products requiring disposal in landfills" and other areas of waste termination, it should come as no surprise that the benefits observed by the environment are large (Schlarb, 2001). Since the EIP is attempting to recover resources from byproduct streams belonging to the community, tenants, and local businesses, a decrease in the demand for natural resources is observed. Concurrently, this diversion of byproducts leads to a reduction of the waste that is appearing in environmentally detrimental areas (e.g., sewer system, landfill, hazardous waste treatment facilities, chemical waste storage, etc.). With fewer wastes being emitted from the industrial ecosystem (which would include the surrounding businesses and the community) into the regional ecosystem, the environment is more capable of rejuvenating itself and flourishing in a sustainable manner. Lastly, since co-location is in effect, fewer supply vehicles (like dump loaders, rail barges, and 16-wheeler trucks) will have to regularly transport needed resources to the EIP inhabitants; the symbiotic linkage infrastructure reduces stress on a heavily polluting transportation system (Lowe et al., 1997). A summary of benefits to the environment, community, and companies involved can be seen in Figure 6.

Potential Benefits of Eco-Industrial Development

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

Figure 6: Summary of Benefits to each member of the Industrial Ecology (Koenig, 2005)

1.4 – Examples of EIP Development Worldwide

1.4.1 – Kalundborg, Denmark

Kalundborg, Denmark, has been noted as one of the most influential eco-industrial networks because it was the first one ever formed. Contrary to popular belief, Kalundborg is not defined as an eco-industrial park; the most accurate description of it is an industrial symbiosis network. The reason Kalundborg is more of a network than a park is because there is no common management group, all the relations are bilateral (i.e., a contract or agreement that obligates each party to provide a good, service, or monetary amount in return for a good, service, or monetary amount), and, most importantly, the relationships stretch across the region, rather than being contained in one park (Cohen-Rosenthal and Musnikow, 2003). Figure 7 shows the different companies within the network and the byproducts that they exchange. These exchanges were initiated spontaneously and without governmental or private investor planning. Through strong inter-management relationships, dedication to cooperation, and an unusual degree of trust between company managers, discussions began to arise as to how to reuse byproducts that were being thrown out. These discussions turned into actions that made it possible for one of the most complicated networks of waste and energy exchange to take shape (Industrial Symbiosis Institute, 2009).

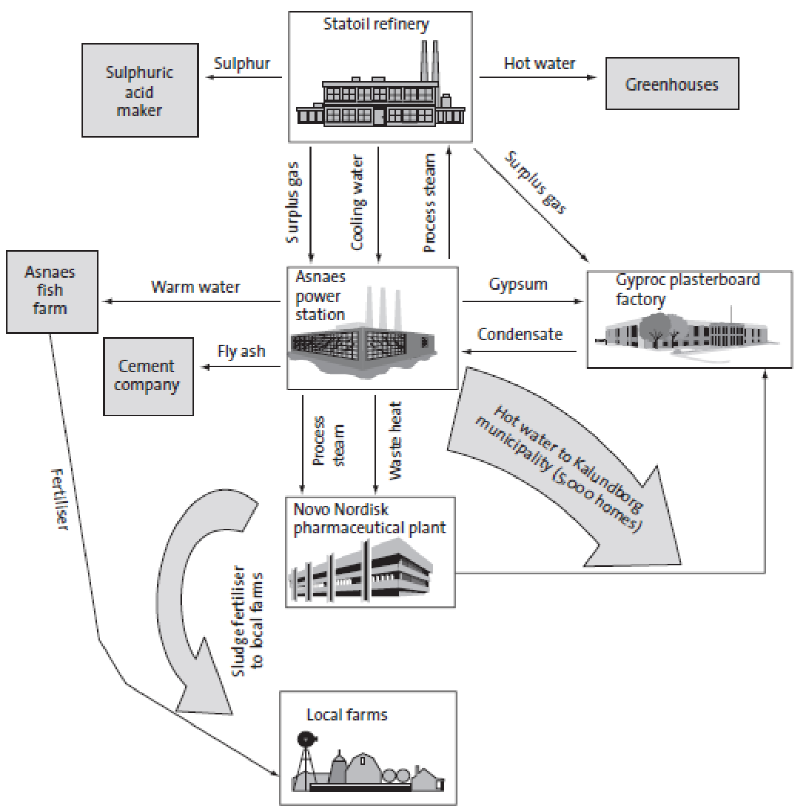


Figure 7: Kalundborg Industrial Symbiosis

Kalundborg's network consists of several key players (a few of which can be seen in Figure 7): Asnaes Power Station, Gyproc (the plasterboard manufacturer), Novo Nordisk (the pharmaceutical manufacturer), Novozymes (the enzyme manufacturer), Statoil (the oil refinery), RGS 9O (the soil remediation company), Kara/Noveren (the waste collection company), and the Kalundborg municipality. Asnaes serves as the anchor facility (i.e., the most important tenant in the park that serves as symbiotic leader and is typically connected to most of tenants and relevant community members) (Industrial Symbiosis Institute, 2008).

The coal-fired Asnaes Power Station produces 10% of the energy in Denmark alone (a reported 1500 MW) (Industrial Symbiosis Institute, 2008). The excess heat generated during electricity production is fed through a system of underground pipes and reused by neighboring tenants and as central heat for city inhabitants. The central heat supplied by Asnaes allows the city to reduce its oil consumption by 19,000 tons per year (Wasserman, 2001). On another front, Novo Nordisk and Novozymes receive 1.5 million GJ of steam annually. This is enough to cover all of Novo Nordisk's steam needs for an entire year and saves Novo Nordisk $1 million annually (Wasserman, 2001). In comparison, this amount of process steam would require an energy generation process that would emit 240,000 tons of CO_2 (Industrial Symbiosis Institute, 2008). Nearby, the power station delivers warm water to a fish farm capable of producing 250 tons per year. This fish farm's operations produce sludge that is sold to the nearby farming community for fertilizer. In another direction, Asnaes sells industrial gypsum (from the calcium sulfate that is recovered from the power plant's scrubber system) to Gyproc, meeting two-thirds of its annual input requirements. Even though Asnaes chose to utilize the slightly more expensive calcium hydroxide scrubber system to decrease its sulfur emissions, the cost of operating the scrubber system is almost entirely paid for through the bilateral agreement with Gyproc. The last byproduct Asnaes produces after the combustion process is fly ash and clinker. 170,000 tons of fly ash and 30,000 tons of clinker are sold to neighboring builders for road construction and cement production (Wasserman, 2001).

Statoil refinery produces petroleum products and, as an effluent, emits flare gas (i.e., burnt off ethane and methane) into the atmosphere. As early as 1972, Statoil decided to quit burning off the flare gas and instead sell it to Gyproc. The plasterboard manufacturer uses the flare gas as a fuel for drying their wallboard product because it is cheaper than oil and easier to maintain. The significance of this symbiotic link is that the flare gas produced by Statoil substitutes for 30,000 tons of coal that Asnaes would have recover. In addition, the sulfur that Statoil removes from the flare gas (before selling the gas to Asnaes) is also sold to a nearby business producing sulfuric acid. An even more substantial symbiotic innovation was developed by Statoil and Asnaes to address Kalundborg's water shortage problems. In 1987, the two companies devised a plan to annually redirect 700,000 cubic meters of Statoil cooling water to Asnaes' water boiler. This led to an environmental improvement in the neighboring fjord, which is no longer forced to receive unnaturally warm water coming from Statoil's operations. In total, Kalundborg's annual intake of new water is 7 million m^3 per year. Through the recycling and reuse of water between entities in Kalundborg, Mother Nature observes a savings of 3 million m^3 of water per year (Wasserman, 2001).

Another early contributor to the industrial symbiosis at Kalundborg is Novo Nordisk. This company has piped 3000 cubic meters of sludge per day to farmers (who use the biomass as fertilizer) within 40 miles of their facility for free since 1976. This amount of fertilizer being derived from a byproduct results in an annual savings of approximately $50,000 per year per farm. In addition, the infrastructure for these pipes was paid for by Novo Nordisk because the sludge disposal cost (under Danish environmental regulations) is fairly high. The money saved from decades of avoided disposal costs more than pays for the infrastructure needed to deliver the sludge. These sludge regulations, and many other Danish regulations that would be considered strict in other parts of the world, led to innovation and market realization that would not be capable without the concept of industrial symbiosis and industrial ecology more generally (Wasserman, 2001).

For brevity, not all the parties involved in industrial symbiosis at Kalundborg will be discussed. Asnaes, Statoil, and Norvo Nordisk represent some of the earliest and most important tenants in Kalundborg's pursuit of an optimal triple bottom line. For this reason, they deserve special attention that explains how they contribute to the eco-industrial network at Kalundborg. Figure 8 shows a plethora of all the industrial symbioses occurring at Kalundborg and when they were initiated.

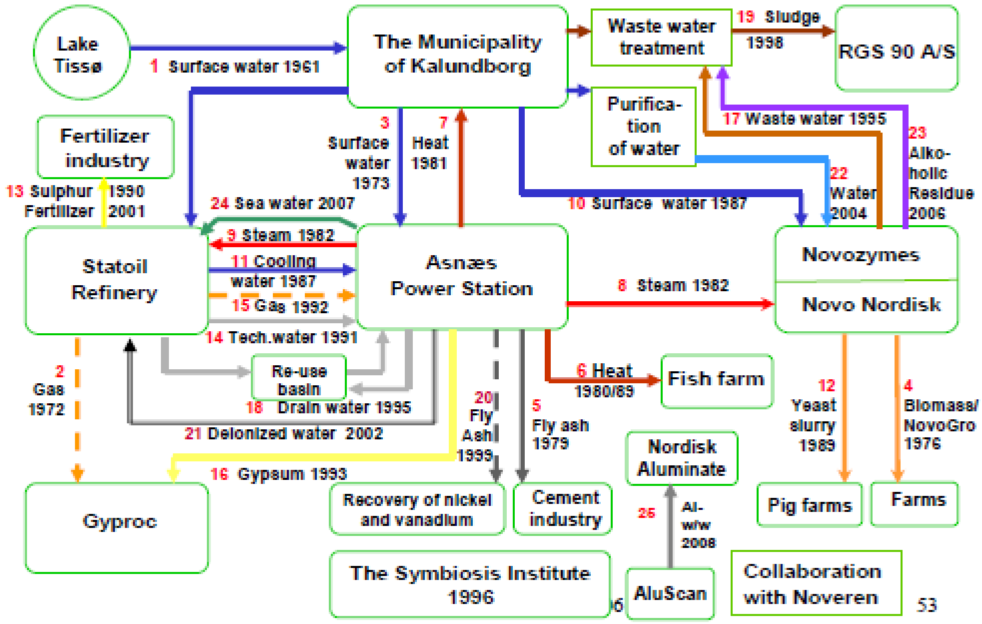


Figure 8: Kalundborg Industrial Symbiosis - Historical Tracking of symbiotic linkages as of 2009 (Industrial Symbiosis Institute, 2009)

1.4.2 – Netherlands

The most notable eco-industrial park project in the Netherlands is the INdustrial Eco-System project (INES). In 1994, INES was initiated by an entrepreneur's association (Deltalinqs) in conjunction with 69 industrial firms, local, regional, and national government, a university, and consulting agencies. Funding for planning costs was provided equally by the government agencies and companies involved. Based on official project publications, the realization costs were in excess of US $100 million. Project management and planning group participation were largely headed by Deltalinqs in association with the 69 firms. Before sites were even considered (from 1991 to 1994) for development, Deltalinqs supervised the development and implementation of environmental management systems within the industrial firms. In contrast to Kalundborg, no local champion or anchor tenant was named because Deltalinqs wanted to avoid the idea of favoritism among companies;

considering they were all generally suitable for the job. The site selected was a brownfield site (the Rotterdam Harbour and Industry Complex) over 7,413 acres large and located in a harbor (Heeres et al., 2004, Baas and Boons, 2004).

At the onset, fifteen different industrial ecology projects were identified. Of these fifteen, only three were selected for future feasibility studies, one was commercialized separately, and one more project (the Demand and supply of steam project) was explored beyond the INES project. At the second phase of the project (running from 1999 to 2002), the INES project became the INES Mainport project and was given a new key objective: "to initiate and support activities within the Mainport that contribute to sustainability of industrial operations and future port development" (Baas and Boons, 2004). The main difference between the INES Mainport project and the original INES project (lasting from 1994 to 1997) was in their strategy for decision-making. The original project was operated by a small team consisting of two university researchers; the Deltalinqs project leader, a consultant, and a company representative. The later project initiated a strategic decision-making platform that included the following participants (Baas, 2008):

- Deltalinqs – supervising the projects;
- Representatives from major companies in the area;
- The Dutch National Industry Association;
- The Dutch National Ministries of Economic Affairs (EZ), and Environment & Spatial Planning (VROM);
- Province of Zuid-Holland;
- The Municipal Port Authority;

- The Regional Environmental Agency (DCMR);
- Regional Water Management Agency (RWS/directory Zuid-Holland);
- Provincial Environmental Association (MFZH); and
- The Erasmus University.

In 2000, approximately 2200 MW of waste heat were emitted to the air and between 4000 and 6000 MW of waste heat was emitted to the surface water. To take advantage of this negative environmental impact, the demand and supply of steam project turned into a full energy and waste heat exchange on a cluster basis. A cluster basis was implemented because, as the size of the industrial park grows, it becomes more expensive to build piping greater distances in the effort to fully network INES. Clustering the piping networks allowed for energy and waste heat exchange between nearby groups of localized firms, as opposed to linking relatively distant firms interested in exchange.

Ironically, a compressed air supplier, outside of the park, learned about the initial compressed air project that was started as one of the original INES sub-projects. This project was abandoned because the tenants and their suppliers thought it would be too complicated and risky a system to implement. The compressed air supplier mentioned earlier learned of this project and decided it was feasible if trust was built between small numbers of companies. So this compressed air supplier built trust amongst four INES companies in order to exchange knowledge about operations. By focusing on a smaller number of companies, the scale of the project was dramatically decreased, making it even more feasible. The compressed air supplier invested in the installation of pipelines, runs the process, maintains the system and is responsible for a continuous supply of compressed air. As a result, savings of 20% in both costs and energy, and a reduction in CO_2 emissions (from reduced energy usage) to 4150 metric tons per year have been observed in preliminary studies. The four firms were connected and operating in collaboration with the compressed air supplier in 2000, and by 2003, fourteen companies were participating in the compressed air network (Baas and Boons, 2004).

This compressed air network exemplifies what can happen if individual companies take the initiative to learn how byproduct exchanges can occur by starting on a smaller "cluster" basis, and scaling up as demand grows and economies of scale increase. However, to make more sweeping changes, the Dutch make it clear that industrial associations must play a big role in building trust, managing information flow that will stimulate byproduct exchange, and lobbying for governmental support (both in the form of funding and eco-industrial regulations/policies). This would explain why the Rotterdam harbor area continues to serve as home to a growing eco-industrial network and a growing number of industrial symbioses projects to this day (Baas 2008).

1.4.3 – China

China is home to a concept that is strikingly similar to industrial ecology. Andreas Koenig created a guide for Chinese government officials and industrial park managers in support of the EU (European Union) – China Environmental Management Cooperation Programme. Koenig (2005) defines the circular economy as:

> “a holistic economic concept which seeks efficiency in resource use through the integration of cleaner production and industrial ecology into a broader system encompassing industrial firms, networks or chains of firms, eco-industrial parks, and regional infrastructure to support resource optimization.”

Essentially, the circular economy defines a vision for eco-industrial development on a national level. The circular economy can benefit countries like China because it is the world’s most populous country with an estimated 1,330,141,295 people (*The World Factbook 2011*). For this reason, the application of the circular economy is being supported by the Environmental Management Cooperation Programme (EMCP) in collaboration with China’s State Environmental Protection Administration (SEPA). By mid-2005, SEPA had approved 12 EIP demonstration projects. To show further support, the EMCP and SEPA supported four pilot projects; the largest and most promising EIP project being the Shanghai Chemical Industrial Park (SCIP) (Koenig, 2005).

The SCIP development started in 2001 on the southern coast of Shanghai and serves as their first industrial zone to specialize in petrochemical and fine chemistry plants. With a total area of 7,265 acres (see site plan in Figure 24 of the Appendix), it is one of China’s largest industrial development projects, making it the ideal first candidate for eco-industrial development. Three central entities comprise the SCIP’s management structure: the SCIP Leadership Group (the "Leadership Group"); the SCIP Administration Committee (the "Administration Committee"); and the SCIP

Development Co., Ltd. (the "Development Company"). The Leadership Group is the highest authority of the three and is responsible for establishing general policies and principles for SCIP. The Administration Committee is the “arm of the Shanghai government” and takes precedence over the SCIP Development Company in decision-making. The Administration Committee is responsible for development planning, industrial policies, land-use planning, administration of construction projects, evaluation and approval of investment projects, coordination relations between site companies and public agencies, and provides general guidance and service to park inhabitants. The Development Company is the liability body for the development and construction of the EIP and mostly consists of members from Shanghai Petrochemical and Shanghai Huayi (Group). The Development Company receives government investment to fund the EIP development project. This Development Company uses these funds to develop infrastructure in SCIP, recruiting tenant companies, facilitates approval of potential tenant companies, and provides services for inhabitants of SCIP (Lowe et al., 2005).

In 2004, the Shanghai Municipal Development and Reform Commission instructed SCIP management to begin transforming the chemical industrial park into an eco-industrial park (Lowe et al., 2005). To promote byproduct exchange immediately, the SCIP hosted an International Green Chemistry conference in 2004 to enable recruitment of specialty chemical companies interested in exploring byproduct exchanges between chemical companies (Koenig, 2005). From this, and other industrial networking activities, SCIP management has elected 40 global companies to co-locate into SCIP; the following companies play larger roles in the byproduct exchange projects at SCIP (Lowe et al., 2005):

- Multi-national Companies: British Petroleum (or, BP), BASF, Bayer, Huntsman, Air Products and Chemicals, Ltd., Degussa Specialty Chemicals (Shanghai) Co., Ltd , Lamberti Chemical Specialties (Shanghai) Co, and other international petrochemical and utilities corporations.
- Chinese Companies: SINOPEC, GPCC, SHYG, SCAC, Shanghai Shenxing Chemical Co, Shanghai Tianyuan Group, Shanghai Chlor-Alkali Chemical Co., Ltd., and Shanghai Coking.
- Utilities Companies: SUEZ, Vopak Shanghai Logistics, Air Liquide, and Praxair.

These companies contribute the most by funding a large number of byproduct exchange projects. These projects work in their favor; potentially leading to marketable products produced from low cost byproducts. However, these projects require large investment capital, time and resources in developing the conceptual processes and operations proposed by the projects. Of the many projects underway at SCIP, eight stand out as essential. A product flow chain of these byproduct exchanges can be seen in Figure 9, while a more comprehensive diagram describing the byproducts flows internal to and external to SCIP can be seen in Figure 10.

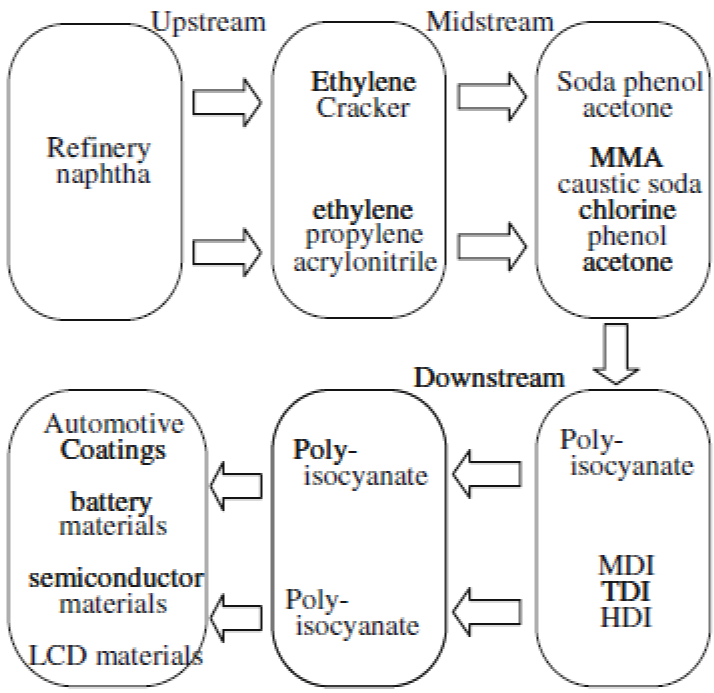


Figure 9: SCIP Byproduct Exchange System Proposed by Projects. MMA = methyl methacrylate acid; MDI = methylene diisocyanate; TDI = toluene diisocyanate; HDI: hexamethylene diisocyanate. (Jiang, 2005)

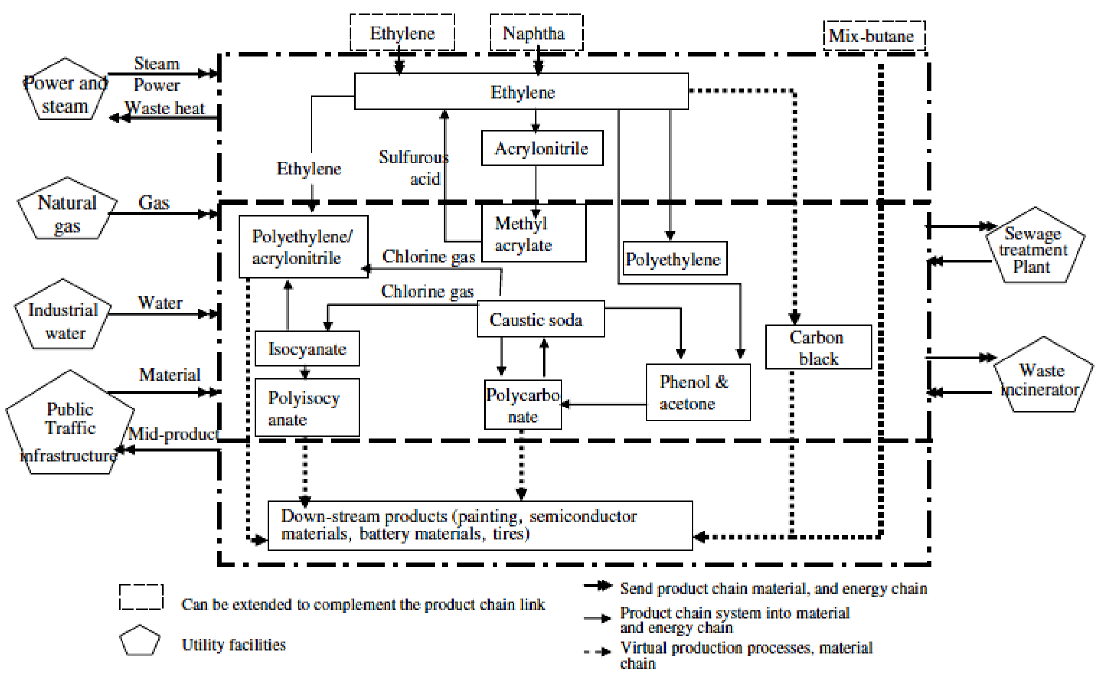


Figure 10: SCIP Byproduct Exchange on Regional Level (Jiang, 2005)

The 900,000 tonnes/annum (t/a or metric tons per year) Ethylene Cracker Project includes SINOPEC (anchor), Shanghai Petrochemical Company, and British

Petroleum East China Investment Co., Ltd and required a total investment of US$2.73 billion. The partnership of companies formed around this project is called SECCO. This process stream begins upstream with SECCO where the anchor ethylene plant produces the following primary products (valuable for their "building-block" like chemical properties and capabilities):

- Ethylene produced at a rate of 900,000 t/a;
- Butadiene (and Butenes) produced at a rate of 90,000 t/a;
- BTX aromatics (or Naphtha) produced at a rate of 500,000 t/a;
- Propylene Polymers (or Polypropylene (PP)) produced at a rate of 250,000 t/a;

Shanghai Petrochemical Company partakes in oil refining (i.e., "Refinery Naphtha" in Figure 9) and subsequent ethane production as the initiator of upstream projects. These upstream projects produce byproduct chemicals that feed into midstream projects focusing on the production of polycarbonates. Later, these midstream projects produce byproduct chemicals that flow into downstream projects focused on the production of polyisocyanates and specialty-chemical products (e.g., automotive coatings, battery materials, semiconductor materials, and LCD monitor materials) (Lowe et al., 2005).

In addition to these projects, several other non-chemical production related projects are underway at SCIP. The Residual Heat Electricity Generation Project was initiated to utilize wasted steam from production processes and hazardous waste disposal procedures at the park. Its chief goal is to reduce the amount of heat pollution experienced by the surrounding environment. The Constructed Wetland for Sewage Treatment Project was introduced to provide tertiary treatment for sewage. This treatment would occur on account of natural biological actions conducted by plants, microbes, and soil in the wetland. The Ecological Forest Shelter Belt Project was developed to reduce emissions of air pollutants into the surrounding region. The SCIP utilities personnel would plant a shelter belt consisting of a tree zone, a shrub zone, and a grass zone; each zone containing plant species that are scientifically proven to absorb emissions. In fact, designers predicted that the dense forest shelter could reduce emissions of sulfur dioxide by 20%, carbon monoxide by 35% and carbolic acid by 26%. The Gray Water Recycling Project planned for the building of a gray water recycling pipeline network that would collect water from each facility at SCIP, send the water to a water treatment facility, and recycle the now treated water for irrigation, cleaning, landscape design, and a host of other non-potable water activities. The Sludge Dehydration and Comprehensive Utilization Project was initiated to transform non-poisonous waste sludge, using dehydration treatment, into a feedstock raw material for roadbeds, fire resistant materials, or floor tiles. The Comprehensive Utilization of Hydrochloric Acid By-Product Project was initiated to take advantage of the excess hydrochloric acid being produced at SCIP. The byproduct hydrochloric acid can be electrolyzed to produce chlorine and hydrogen. Lastly, one of EMCP's pilot projects led to development of the unique Emergency Response System. This system consists of an Emergency Response Center (ERC) and a health clinic (providing economies of scale for all inhabitants) that work in collaboration with public security (police), fire-fighting, and other relevant emergency personnel. The functions of the ERC include information collection, transmission, local safety monitoring, accident prevention, emergency response command, treatment (Lowe et al., 2005).

SCIP serves as an example of how to apply industrial ecology on a large and complicated level. Chemical processes produce a large number of byproducts that are often disposed of in environmentally unfriendly ways. An EIP like SCIP demonstrates that it is possible to find alternative uses for these byproduct chemicals as long as the production chain is designed with care and consideration. SCIP takes advantage of symbiotic chemical byproduct streams, but at a high initial investment cost. However, for the companies willing to invest in co-location and take advantage of the byproduct exchange projects ongoing at SCIP, the reward is a winning triple bottom line and the designation as a contributor to China's Circular Economy.

1.4.4 – Australia

During the early 1990's, Australia was experiencing a national problem with its waste management system. On a more localized level, most states and local government agencies had policies and procedures designed to encourage recycling and reduce the rate of waste creation. However, even with these measures in place, Australia still needed to reduce its greenhouse gas emissions in order to be in compliance with the Kyoto Protocol defined targets. Recall that the Kyoto Protocol calls upon each nation in the United Nations to reduce their greenhouse gas emission rate to a percentage relative to how industrialized the nation in question is. By 1996, the Queensland State Government attempted to reduce waste and emissions, produced mainly by industrially zoned areas, by seeking advice on how to synthesize industrial ecology with their economic and community development plan (Roberts, 2004).

In 1997, the Australian Housing and Urban Research Institute (AHURI) began a two part research project investigating the feasibility for EIP development in Synergy Park's region (or industrial ecosystem). The first part of the research was essentially an industrial ecology literature review. This was necessary because it helped the research team develop principles and planning guidelines for the development of the EIP. The second part of the research took the research team to the industrial ecosystem in question. The research team was responsible for conducting surveys and interviews with firm managers located on, and community groups living adjacent to, the industrial parks in southeast Queensland. The results were not pleasing. Even though it was expected that these two groups would not be knowledgeable about the (then) young concept of industrial ecology, the research team did not expect to find opposition from both business and community groups. More specifically, the business groups disliked the idea of co-locating two or more industrial activities that their experience helped them conclude were incompatible. In addition, the classic "not in my back yard" viewpoint (i.e., public sentiment towards new large-scale developments [typically industrial or utility related] intending on initiating near residential and commercial zones) came to represent the majority of thoughts coming from residential and commercial community members in the area (Roberts, 2004).

The second research effort demonstrated a lack of consensus. If not addressed early enough within the design and development process, a lack of consensus between stakeholders and decision-makers can lead to significant delays. For example, political delays can be initiated by community groups who have convinced government officials that their community is at risk if the development continues (Mintzberg et al., 1976). During the time, uncertainty and unfamiliarity initially impeded EIP development, in that part of Australia because industrial ecology's body of knowledge – describing success stories, proven benefits, and core principals – was not made readily available to community groups and members prior to the survey and interviews. In addition, the nationwide attitude towards the manufacturing industry may have been negative because of the increase in outsourcing of manufacturing jobs (as a result of very low foreign labor costs). However, it is still important to note that, generally, if developers teach the principals of industrial ecology to community groups early enough and allow community leaders to share a role in decision-making, then this will develop trust and community support for the development project (Roberts, 2004).

In 1998, the Department of State Development, a local council, and a private developer began planning and development for Australia's first EIP: the Synergy Park (located in southeast Queensland, roughly 13.7 miles west of Brisbane). This project intended to transform a 91.4 acre industrial parcel within Carole Park (an industrial park constructed during the 1960's) into an EIP. Later that year, the Synergy Park Unit Trust was formed to develop, recruit tenants for (i.e., interview, screen, evaluate, select, and draft lease for incoming tenants) and market Synergy Park, while the role of the state and local government was to administrate town planning, provide services and infrastructure, and to engage in community consultation. The Synergy Park Unit Trust decided to focus on the food and beverage industry for recruitment because of the region's following characteristics (Roberts, 2004):

- Lockyer and Bremer valleys, the most fertile agricultural area in Australia, lay west of Synergy Park;
- Carole Park possessed water and sewage capacity already (saving on infrastructure development costs);
- Carole Park possessed excellent transportation linkages; and
- A previously unemployed workforce (from nearby Ipswich), familiar with many diverse manufacturing processes, can be trained with Carole Park's training infrastructure and adapted to the food and beverage industry.

Four sub-projects have emerged from the development of Synergy Park and have led to growing economies of scale for inhabitants and waste diversion from the environment. The first sub-project planned development of a central warehouse that networks with the logistics management system project. The central warehouse will operate on a per-kilo, carton, or pallet rate so tenants can use it on an as-needed basis. This warehousing system reduces overall vacancy within the warehouse, which translates to lower maintenance and utility costs (Roberts, 2004).

The second sub-project is the logistics management system. At the very least, the shared logistics and routed vehicle management system makes it possible for a delivery truck (i.e., an auxiliary service provider) to deliver more than one company's goods to a common destination, utilizing the truck's capacity and reducing the trip length. The system will give inhabitant manufacturers (whose products are bought in a supermarket or grocery store) the ability to register their products by bar code to collect sales data. This data can be relayed back to them and used to strategically determine what quantity and product they need to produce for the next day's just-in time delivery. This continually updated system is quite expensive and hard for individual firms to acquire, making co-location that much more beneficial (Roberts, 2004).

The third economy of scale is in the area of energy supply. A co-generation plant (to be developed circa 2004) provides inhabitants with electrical energy and heat. To generate heat for park inhabitants, steam typically vented into the atmosphere is redirected so its energy content can be reused. This saves inhabitants from having to invest in land, capital, and operational costs that are required to possess its own boiler. Each inhabitant is not limited to the amount/form of energy they may receive from the co-generation plant; this can account for the colder winter and fall months (Roberts, 2004).

The last sub-project focuses on the effluent disposal and treatment network This network begins at the tail end of each tenant and is where different effluent streams are segregated early. Trade waste (i.e. contaminated, non-reusable water) and high quality waste water are piped separately to the pre-treatment plant. At the pre-treatment plant, the trade wastes are treated with respect to local standards and transferred to the Council sewage treatment plant. The high quality waste water, on the other hand, will be treated and reintroduced to factories for non-potable water activities (e.g. wash downs or water source for steam generation at co-generation plant) (Roberts, 2004).

As of 2010, there are an estimated 193 EIP and EIN projects outside of the United States that are currently in their pre-development, feasibility analysis, or project support building phase. Of the 193 projects outside of the U.S., only 61 are operational and actively recruiting tenants and an additional 11 are under construction (Davis, 2010).

1.5 - Examples of EIP Development in the United States

As of 2010, there are an estimated 34 EIP and EIN projects within the United States that are currently in their pre-development, feasibility analysis, or project support building phase. Of these 34 projects within the U.S., only six are operational and actively recruiting tenants, while one is still under construction. The following is a list of these six operational (and one under construction) EIPs and their current statuses (Davis, 2010):

1. Cabazon Resource Recovery Park in Indio, California;
2. Catawba County Regional EcoComplex and Resource Recovery Facility in Catawba, North Carolina;
3. Devens Planned Community in Devens Massachusetts;
4. Guayama Eco-Industrial Park in Guayama, Puerto Rico;
5. Kansas City Regional By-Product Synergy Project in Kansas City, Kansas;
6. Stoneyfield Londonderry Eco-Industrial Park in Londonderry, New Hampshire; and

7. (Under Construction) Brownsville Eco-Industrial Park in Brownsville, Texas.

Due to government decisions (that unsuccessfully promote industrial ecology development or unintentionally hinder eco-industrial development teams), a large percentage of the thirty EIP projects initiated no longer exist today. For example, the EPA's Eco-Industrial Park Project Implementation Plan ("Implementation Plan") initiated in 1994 failed because it never addressed *who* (i.e., what entities and organizations) will do *what* eco-industrial development activities and never fully defines *what* an EIP is. The EPA may have based their Implementation Plan on international eco-industrial development examples (e.g. Kalundborg, the INdustrial Eco-System in Netherlands, etc.) that exhibited private developers autonomously initiating eco-industrial development projects. However, a vast majority of EIPs are initiated by the government. In fact, EIPs in which government agencies participate beyond the project initiation and funding phase (i.e., during subsequent EIP design and development phases) experience fewer failure rates. According to Gertler (1995), The Implementation Plan seemed to be a "patchwork expression of stakeholder interests." The Implementation Plan should be a comprehensive set of guidelines that defines design strategies of EIPs while ensuring consensus between decision-makers and stakeholders by synthesizing their interests.

As a second example, the outdated (enacted in 1976) Resource Conservation and Recovery Act (RCRA) limits the use of potentially reusable byproducts in order to protect citizens from known dangers that may have existed then but may no longer exist today (thanks to evolving manufacturing processes and advancements in materials production and utilization research). Because of the RCRA, about one-third of the industrial byproducts produced have been given the ‘hazardous label,’ and deemed non-reusable (Gertler, 1995).

Based on the international EIP examples presented in earlier, it appears that the government can help byproduct exchange in a number of ways. For example, to improve the U.S.’s EIP success rate, each state’s environmental protection agency should be given the ability to override RCRA ordinances governing reuse and recycling activities. For state environmental protection agencies to gain the ability to override RCRA ordinances, they would have to sponsor a scientific investigation proving that a previously defined hazardous byproduct can be treated, rendered non-hazardous, and safely used in consumer products without negative impacts on stakeholders (relative to negative impacts caused by the byproduct’s substitute virgin material).

1.5.1 – Devens, MA

The Devens Regional Enterprise Zone (“Devens”) serves as the first eco-industrial park development project conducted in the United States. In 1994, part of a former Army base in Massachusetts (i.e., Ft. Devens) was chosen to be redeveloped into an eco-industrial park and sustainable mixed use community. The Devens Enterprise Commission (“Commission”) found leadership from Peter Lowitt of Indigo Development (an eco-industrial development company). The Commission acts as a regulatory and permitting authority for Devens. In other words, the Commission functions as a “board of health, conservation commission, zoning board of adjustment, and planning board." The twelve commissioners are unpaid and live within the communities surrounding Devens. Six of these commissioners are nominated by the town meetings of Ayer, Harvard, and Shirley, and the remaining six commissioners are elected by the Governor (Hollander and Lowitt, 2000). The Commission decided to redevelop 1,800 acres of the total 4,400 acres available. The project met qualifications for designation as a Superfund site, and was granted $300 million to begin cleanup and infrastructure development. The Superfund was set up by the US-EPA to offer financial support to brownfield site redevelopment projects that require site remediation and extensive environmental cleanup prior to EIP construction. In addition to public funding, The Commission gained over $2.1 billion in private investment support for new facilities at the site. The 98 companies that decided to participate in the project brought with them 5,000 EIP employee positions (NJMEP, 2010).

An important component to Devens' environmental awareness is the EcoStar environmental program. The EcoStar program is located in the Devens Eco-Efficiency Center and uses 25 standards to evaluate company environmental performance. It is the tool through which the Commission supports business collaboration to utilize byproducts, promotes sharing of training costs through multi-tenant joint training (by offering training facilities at the Devens Eco-Efficiency Center), share transportation resources, and hold meetings and activities that promote EIP cohesion (NJMEP, 2010).

From October 1999 to February 2000, surveys were distributed to companies operating in Devens to determine potential opportunities for industrial symbiosis.

These surveys focused on defining both existing and future industrial activities that could be altered to fit the industrial ecosystem approach. The results from this survey comprised of confidential data about each tenant's production and operations systems; this information was kept secret and aggregated with other tenants' data to form general trends useful during EIP design. The Commission concluded that five major themes should define Devens: (1) material, water, and energy flows; (2) companies within close proximity; (3) strong informal ties between plant managers; (4) minor retrofitting of existing infrastructure; and (5) one or more anchor tenants (Hollander and Lowitt, 2000).

From the results provided by the survey in early 2000, twelve Devens tenants were found responsible for using, discarding, recycling, consuming, producing, or purchasing the largest volume of materials that flows through the EIP. These materials include the following (in order of volume consumed): corrugated cardboard, paper, plastic, metal scrap and chips, wooden palettes, and machine oil. To implement industrial ecology, the Commission needs to close these six major material flows and establish symbiotic connections among existing tenants, while simultaneously seeking new tenants that can create symbiotic connections between tenants and the community via material processing. For example, a company could be recruited to reprocess plastic. If the reprocessed plastic is, for example, a thermoplastic, then this material could be used by the plastic reprocessing tenant to create their own family of plastic products, or it can be sold to tenants for their production needs (as long as it meets quality requirements). Either way, the plastics material flow would serve as one example of a closed loop within the walls of

Devens. In addition to materials flows, Devens has plans for water cascading. Water cascading is a process that takes grey water from one company, sends it to a water treatment plant for treatment, and forwards the treated grey water to a second company for their non-potable water needs. This process of recycling, treating, and redistributing water between companies can be extended throughout Devens and can contribute to lower water usage on a park-wide level. Using the same theories as water cascading, energy cascading has been investigated to see how wastes (typically in the form of heat loss) from high quality electricity can be recaptured and utilized for low quality electricity needs (Hollander and Lowitt, 2000).

The next major theme that Devens is focused on is having companies in close proximity. Devens utilized industrial clustering by creating the following six separate industrial areas: Jackson Technology Park, Robbins Pond Industrial Park, Devens Industrial Park East, Devens Industrial Park West, and the Environmental Business Zone. The participating companies are in close proximity within these industrial clusters and, in some cases, even co-located. Each industrial area is well connected with the others by roadway (Hollander and Lowitt, 2000).

Thirdly, the Commission promotes strong informal ties between plant managers at Devens in order to catalyze symbiotic opportunities. This is being promoted because plant managers do not know one another personally; however, at Kalundborg, personal relationships between managers have proven to be a commonly overlooked contributor to success. To do this in an inviting manner, the Commission utilizes the Devens Eco-Efficiency Center to hold semi-monthly luncheons where guest speakers address plant managers about operations and management topics. This luncheon may unite plant managers with common problems, give them guidance from knowledgeable guest speakers, and promote a more collaborative park environment (Hollander and Lowitt, 2000).

Fourth, the Commission promotes minor retrofitting of existing infrastructure. To maximize the return on investment for their firm, tenants typically need to modify their operations and processes in order for a more reusable byproduct to be introduced into the EIP material flow loop, or to enable the use of a byproduct flowing in from another tenant. Prior to retrofitting, a park-wide water, energy, and material balance must be conducted to determine the most economically efficient way to implement the needed infrastructure (Hollander and Lowitt, 2000).

The last theme the Commission promotes is the inclusion of one or more anchor tenants. The Devens Regional Enterprise Zone is currently in possession of one tenant that can play this role: the wastewater treatment facility. In general, an anchor is necessary to capitalize on a missing link in one of the existing open-loop material flows. At Devens, the wastewater treatment facility is ideal because it physically connects with each tenant in Devens and, after upgrades, will have the ability to process both water and waste flows. If the reprocessed water meets quality requirements, then it can be reused for non-potable activity by the tenants and the surrounding communities, thereby closing the regional water loop (Hollander and Lowitt, 2000).

Today, Devens Regional Enterprise Zone is still thriving and recruitment for light to medium industrial tenants is stronger than ever. The Devens EIP has come a long way; from a governor created (in 1991) Fort Devens Redevelopment Board to a fully functional Devens Enterprise Commission (which is “vested with broad regulatory authority related to land use planning and permitting functions”) (Lowitt, 2009). Within the park, roads and infrastructure continue to be developed, the Commission continues to grant permits, and regulations begin to change for the better. It is important to note how effective a community-based design and development commission (or authority), like the Devens Enterprise Commission, can be in implementing an EIP when working closely with a private consultant or development corporation.

1.5.2 – Londonderry, NH

Forty miles north of Boston, there is a sub-urbanizing community of roughly 27,000 people called Londonderry, New Hampshire (Deutz et al., 2004). All the eco-industrial development rumors began before 1996, when a plastics recycling company approached Stonyfield Farms Yogurt (a New Hampshire leader in sustainable business practice) about reusing its grey water to rinse plastics. In addition to the grey water collection, the plastics recycling company also wanted to set up a recycling operation (that they one day hoped to turn into a full eco-industrial park), on the vacant town-owned land nearby Stonyfield Farms Yogurt. This caught the attention of the Town of Londonderry; fortunately, they fully supported the eco-industrial park proposal. In 1996, a vision statement was established; leading to the development of a set of covenants and governance system soon thereafter (NJMEP, 2010). This body of work detailed what was expected of future tenants seeking to develop within the Londonderry Eco-Industrial Park (LEIP). For example, future tenants were expected “to develop an environmental management system, track their resource use, set environmental performance goals, perform third party ecological audits, and report progress to the Community Stewardship Board [(i.e., a citizen committee)]” (Deutz et al., 2004).

Figure 11: Tenant Layout at Londonderry EIP (Garron, 2009)

Even though the LEIP is still open Stonyfield Farms Yogurt has moved from the LEIP site to a highly sustainable production facility called the Yogurt Works Facility (“Our Yogurt Works Facility, Water, Waste, Green Building, Energy, People,” 2011). An updated layout of the LEIP can be seen in Figure 11. Lately, the LEIP has recruited AES – a power company that will develop a 720 MW combined cycle natural gas power plant. AES will even introduce an inter-regional symbiotic link to the LEIP by accepting treated wastewater pumped from the City of Manchester's Waste Water Treatment Facility for power production processes. In addition to AES, a medical supply distribution firm (Gulf South Medical Supply), software firms, and Bosch Thermo-technology Corp. (heating and hot water products) are located within the LEIP. It is still relatively early in LEIP's timeline, so the single symbiotic link should come as no surprise. However, the Town of Londonderry is still supporting the LEIP and has not abandoned its vision. In fact, the Manchester-Boston Regional Airport access road project is due for completion in 2012. Once completed, it will provide access to over 1,000 acres of commercial and industrial "to be developed" land (Garron, 2009).

Londonderry EIP and Devens Regional Enterprise Zone represent two relatively successful EIP development examples. A growing interest continues to form around industrial ecology here in the U.S., and there are a number of EIP projects being initiated to create real industrial ecologies. It is important to note a common theme that most EIPs continue to exhibit: a central information sharing center where the community can connect with the EIP (e.g. via community and business association meetings, EIP open houses, and other public events); where the EIP tenant managers can connect with one another (e.g., during design charrettes, monthly luncheons, or EIP management board meetings); and where the EIP employees across different firms can connect with one another (e.g., at the cafeteria, at the medical wing, during joint-tenant training exercises, or during other multi-tenant collaborative meetings). The human side of industrial ecology is often overlooked, but central-common facilities like the Devens' Eco-Efficiency Center play an important role in developing and maintaining trust filled and lasting connections between the human members of the EIP and the members of the surrounding community. For more information on the United States' efforts towards eco-industrial development (up to 2005), one may refer to Table 41 of the Appendix.

1.6 – Research Questions

The research questions this thesis intends to answer are as follows:

- How are EIPs currently developed?
- What are the most important objectives of EIP development projects?
- What are the key decisions that need to be made during EIP development projects?
- How can these decisions be organized into an EIP design process that is more consistent with (and more capable of advancing) the most important objectives?

1.7 – Thesis Overview

Chapter 1 has just presented a background on what sustainable development, industrial ecology, the triple bottom line, and EIPs are. It presented the benefits that can be experienced after an EIP begins operations. In addition this chapter discusses a few real-world examples of EIP development projects from the U.S. and around the world that have advanced triple bottom line (or TBL) objectives.

Chapter 2 goes into more detail about the concept of EIPs and discusses the EIP design and development process. The difference between planning for and developing a regular industrial park, versus planning for and developing an eco-industrial park, are discussed. Common decision makers, stakeholders, steps taken during development, and important objectives are discussed for a better understanding of the EIP development process. Next, an analysis of 21 EIP development projects is presented and it highlights each of the projects' routines, decision process types, stimuli, and solutions. Much of this analysis follows Mintzberg et al. (1976) and their Structured Decision Process.

Chapter 3 discusses the general EIP development process (or the GEIPDP). This chapter will present how the GEIPDP was created why it expresses a sequence of decisions that are aligned with the triple bottom line. It will then explain why there was a need for revisions to this general development process followed by a discussion about how the revised EIP development process (or, the REIPDP) does a better job of ensuring advancement of TBL objectives. An explanation over key decisions made during EIP development processes and how they link (directly and indirectly) to the TBL objectives is also discussed.

Once a general EIP development process has been agreed upon (i.e., the REIPDP), chapter 4 presents what the contingency decision making framework (or, the CDMF) is and how it can be utilized to ensure that the correct decision making method is being used during each phase of the REIPDP.

Chapter 5 presents a detailed example of a key decision that the EIP development team must make: selection of business and auxiliary service tenants for empty lots within the EIP. This example is based on real-world data from an Oak Point EIP feasibility study that was created to promote eco-industrial development in the South Bronx area. Assumptions and simplifications are discussed as well.

The final chapter discusses the summary of findings, limitations, contributions, and future work.

Chapter 2: The Eco-Industrial Park Design and Development Process

The EIP design and development process involves a great number of professional individuals belonging to government agencies, private investor organizations, development corporations, various community groups, industrial association members, business representatives, regional service provider representatives (e.g., solid and water waste management, regional recycling and resource recovery services, utility companies, and more), and leading industrial producers within the region in question. From all these differing backgrounds, one should expect a great deal of technical knowledge to exist, however, the body of knowledge that is attributed to these individuals may not be enough to design and develop an EIP that will improve the region's triple bottom line. An eco-industrial park development team needs to possess a great depth of knowledge and experience within the fields of eco-industrial development and industrial ecology (among other things). Without the relevant personnel controlling critical aspects of the project, the proper goals and objectives may not even be established at the onset of the EIP design and development project, and success (i.e., the advancement of the region's triple bottom line) will not be as likely to ensue.

The discussion in this chapter is based on a thorough review of the literature describing EIP development processes. At the onset of this chapter, the difference in planning for an industrial park vs. an EIP will be discussed with respect to authors known for publishing great bodies of knowledge within industrial ecology and eco-industrial development. This will be followed by a discussion on the characteristics and responsibilities of decision makers and stakeholders of an EIP project. Next, the important objectives (i.e., both general and triple bottom line specific objectives) of EIP development projects will be discussed to present a clear view of what an EIP is attempting to do. Lastly, a presentation and demonstration of how to analyze an EIP development process for alignment with the triple bottom line's objectives will be discussed.

2.1 – Planning for Development Methodologies: Industrial Parks vs. EIPs

2.1.1 – Planning an Industrial Park

The main function of an industrial park is similar to the function of an eco-industrial park: to provide the tenants with the infrastructure needed at a discount by sharing resources with other firms (e.g., buying feedstock materials in bulk to achieve economies of scale or sharing common third party service personnel to achieve economies of scope). The primary actors, at the earliest stages, are the land owner(s), a planning/development team (i.e. private consulting firm or public development agency), the local government (state department), and the community.

The first step in planning an industrial park is to hire a planning team (from here on referred to as the consulting firm). In the United States, public development agencies have taken responsibility for most US industrial parks with larger scale (and often more polluting) manufacturing industries (Lowe, 2001). Private developers tend to focus on parks developed for light industry, warehousing, and distribution. The developer will help the owner manage the complex processes of acquiring land, managing, planning, feasibility studies, and the assembly of an investment strategy (Lowe, 2001). The more important role of the consulting firm is to ensure that the firms requesting to enter the industrial park will be compatible with every other inhabitant included with respect to available resources and infrastructure. Conventional industrial park developers recruit companies on the basis of access to supplies, markets (i.e. demand), workforce capabilities, workforce costs (e.g. labor burdens), transportation access, economic incentives, and quality of life (to the surrounding community members) (Lowe, 2001). Once a location has been chosen, the land can be purchased and zoned as “industrial” by the local government. Depending on the targeted, expected, and existing inhabitants, restrictions will be placed on the industrial zone accordingly.

2.1.2 – Planning an Eco-Industrial Park

Lowe (2001) provides a great deal of insight into the characteristics of a general development process used for EIPs:

> “Eco-industrial park development calls for asking new questions within the context of traditional industrial development processes. Developing any industrial park requires several rounds of planning and design. The team tests project feasibility in greater detail with each stage. The project must satisfy financial, economic development, public planning/zoning, environmental, and technical criteria at each step. Your eco-industrial park team will follow the traditional process, while considering new design options in each phase of project planning.”

The main difference between an EIP and an industrial park is that EIPs provide the involved firms with the ability to exchange byproducts freely and encourage innovation of byproduct usage amongst park inhabitants and external businesses (Lowe, 2001). Many of the planning for development steps are extremely similar, but when it comes to recruiting tenants, EIP developers have to consider several more factors (Lowe, 2001):

- traditional marketing strategies and an EIP's unique advantages;
- economic and environmental goals;
- filling the park and getting the right mix of companies for by-product exchanges; and
- external recruitment (along with internal growth) and local business development.

An EIP development team must consider the characteristics of the local and regional ecosystem, the site's suitability for industrial development, and potential constraints to the pattern of development. This ecological evaluation complements the usual evaluation of transportation, infrastructure, zoning, and other human systems. Developers of EIPs are primarily focused on developing brownfield site (i.e., an EIP developed after mandatory site remediation of an existing industrial-scale facility or former industrial park) as opposed to a greenfield site (i.e., an EIP constructed on undisturbed land from ground up) with the intention of reducing the use of virgin materials to construct and operate the EIP. The incentive is provided by the government, who can offer tax exemptions or subsidies to owners and developers looking to establish a brownfield site EIP. This incentive would need to cover at least the cost of remediation and cleanup of contaminated land and facilities that will be used (Lowe, 2001).

One difference between industrial park planning and eco-industrial park planning rests in the amount of input that eco-industrial park development relies upon from the community. The following quote from Timothy Nolan's presentation at the Eco-Industrial Networking Roundtable (District of North Vancouver, BC – 2004) demonstrates this:

> "Communities contemplating eco-industrial development first need to identify specific goals, the resources needed to meet those goals, and obstacles to meeting goals. Then they must prioritize the goals and the strategies for meeting those goals."

Identification of goals for the EIP development project with respect to the community that it will exist in will help ensure that viewpoints from stakeholders are not being overlooked. Additionally, if the community knows that it is being heard and that its opinion is being respected (by decision makers), then it will be more likely to reach consensus and offer support for decision makers at various points during the EIP development project (Nolan, 2004).

Going beyond the establishment of priorities, prospective challenges, and goals requires an eco-industrial baseline analysis. Without this baseline analysis, it is difficult to plan an EIP development project. Table 1 elaborates on components of a baseline analysis with (1) respect to industrial parks and (2) eco-industrial parks (Nolan, 2004).

Table 1: Traditional Industrial Park Development vs. Eco-Industrial Park Development Baseline Analyses (Nolan, 2004)

TRADITIONAL Baseline Analysis	**EID (Eco-Industrial Development) Baseline Analysis**
Assess land availability - and consistency with the comprehensive plan. **Evaluate infrastructural capacity.** sewer, water, transportation, electric, storm water. **Analyze access to markets.** local markets, regional markets, national markets, obstacles to moving goods and services. **Analyze access to capital.** public sources, private and venture capital, local sources of capital. **Analyze labor force.** size and training level of local workforce, market wages, availability of housing, and access to transportation routes or transit.	**Analyze regional industrial resource flows -** Gather information on material, energy and water flows (inputs and outputs) within a geographic region targeted for EID. Match with projected industrial loads based on profiles of preferred candidate tenants. **Inventory regional and site-specific amenities and infrastructure -** Identify existing and proposed industrial infrastructure, utilities and facilities in region. This would include an analysis of water supplies, existing and potential renewable energy options (thermal and electric). Qualify access to transportation networks and appropriate scale for new industrial ventures. **Collect and analyze data on existing businesses and production activities in community.** What kinds of manufacturing processes and technologies does the existing industrial development use? What technologies could allow both retooling of existing industry for greater resource and economic efficiency, while allowing new industrial development? **Collect and analyze data on material flows in community . inputs, by-products and wastes, product output.** What are the existing household, industrial, commercial, and agricultural waste streams that could be a feedstock for new industrial development, or that could be co-managed more effectively with new industrial infrastructure? **Develop site evaluation and profiles.** Conduct assessments of potential industrial sites in the region to determine options for EID. Determine the feasibility of each site or combination of sites for locating processing and conversion facilities along with manufacturing ventures. Site profiles will include materials handling and storage options, infrastructure assessments, existing assets, community development capabilities, alignment with local policies, and compatibility with regional suppliers. Determine preferred .eco-industrial. site characteristics. **Identify end-users of by-products and wastes produced within the community.**

	Create an energy profile for the community . production, demand, prices, environmental aspects. What kinds and capacity of distribution, generation, and transmission system infrastructure currently exist in the community? How could existing infrastructure facilitate use of waste heat, co-generation systems, distributed generation, or aggregation of energy use? **Natural resources available for development.** What underutilized resources can be sustainably harvested, including forest resources, agricultural resources, minerals, and water resources? **Inventory of local suppliers and services.** What kinds of locally produced goods and services can be used in new businesses, locally capturing the added value of existing businesses? **Review and characterize previous related planning work.**

Recruiting tenants for an EIP is different from recruiting tenants for a regular industrial park because it requires recruiting by degree. EIP developers may choose to start by finding a versatile anchor facility and observing its inputs and outputs. These inputs will define the next tier of tenants that can be coupled with the anchor tenant (Lowe, 2001). Anchor tenants are favorable because they serve as a foundation for what types of byproduct, energy, and waste water flows are possible (given the right businesses and service providers are entering the EIP and engaging in these sustainable projects). However, EIP developments are not required to have a functioning anchor tenant and, in fact, many EIPs do not even contain a designated anchor tenant.

Prior to finding a suitable anchor tenant, a successful EIP development project will require participation from the following stakeholders and decision-makers early in the process (Heeres et al., 2004):

- public sector stakeholders from local, regional and national government agencies;
- representatives of local companies and potential future tenants in the EIP;
- leaders in the industrial and financial community;
- local chamber of commerce;
- labor representatives;
- educational institutions;
- practitioners with the full complement of capabilities needed in the project ([i.e., development team members]): architecture, engineering, ecology, environmental management, and education and training; and
- community and environmental organizations.

Planning an EIP requires selecting pollution prevention projects, and, thus, organizations need to share information between one another that will be used to determine the "nature and number of pollution prevention projects that [can potentially] make up the EIP development" (Heeres et al., 2004). This information can be gathered in the form of a survey or interview that addresses areas like basic company information; products and markets (the company is affiliated with); employee information; raw materials (used in operations and production processes); waste streams; energy usage data; environmental management system statistics (if it exists [highly attractive to tenant recruiters]); manufacturing networks it may belong to; industrial association(s) it is associated with; and future plans for company development (Heeres et al., 2004).

2.2 – Characteristics and Responsibilities of Decision-Makers and Stakeholders

2.2.1 – The Government

The government's role is particularly important in the EIP development process. Their primary goal is to "advocate for maximizing the public value [through] investments in production" and in ensuring that businesses are operating in a responsible manner (Cohen-Rosenthal and Musnikow, 2003). The government promotes increases in public value and tries to reduce negative externalities (associated with industrial production) by implementing pro-sustainability public policies, imposing taxes on unsustainable actions, and distributing subsidies, grants, and other financial support instruments to EIP tenants who can prove that they're meeting sustainable development requirements (Cohen-Rosenthal and Musnikow, 2003).

The policy climate should improve environmental performance of conventional industry and help achieve the triple bottom line for the region. Policy makers need to incorporate EID strategies and systems analysis into their economic development and planning activities. According to Cohen-Rosenthal and Musnikow (2003), such policies:

1. establish a baseline "floor" of environmental performance that protects human health and safety, the environment, and that enforce it uniformly;
2. price resource use and waste disposal realistically to include the costs of adverse ecological and health impacts;

3. promote access to information about voluntary strategies to improve resource efficiency industrial ecology education among)];
4. encourage material exchange;
5. promote proximity to sources of labor [(to reduce employee transportation to and from work)]; and
6. facilitate the [integration] of industrial practices into the urban fabric through cleaner production and use of less toxic processes, intermodal transportation ([e.g., sending/receiving of freight via two or more different modes of transportation]) access, and modern infrastructure networks.

The taxes imposed by the government deter tenant actions that would consequently produce negative externalities. This ensures that tenants are focusing on the impacts their operations may have on the environment and the surrounding community and implementing systems that protect their well being. As an example, the landfill tax provides a landfill tax credit scheme, which enables landfill operators to gain tax credits when they contribute with environmental initiatives (Eco-Efficiency Centre, 2004). This tax credit would not benefit the EIP directly, but it would motivate environmentally friendly efforts by a business partner of the EIP. Even though taxes are a great mechanism for directing firms towards favorable economic development, the government has to take great care in how it imposes them. For example, if the government decides to tax byproducts (like fly ash and other coal combustion products harmful to the environment) coming from power generating Company A, then there will be intended and unintended consequences in result. The intended result will be the implementation of an improved system for capturing coal combustion products, the development of a process that uses different technology (and possibly even a different input resource) to produce power, or a long term investment in renewable energy sources. Either way, Company A will be motivated to produce less coal combustion products and will set goals in that direction. The unintended result will be observed from Company B. Company B is an EIP neighbor of Company A and entered the EIP primarily to capitalize on the coal combustion byproducts produced by Company A. If the government taxes coal combustion products (i.e., a carbon tax), then Company A may reduce its output of coal combustion products to a level that may not satisfy Company B's requirements. Company B would be hurt by a byproduct tax because it may have to purchase more expensive supplier materials to supplement what it receives from Company A, restructure its production system to accommodate this resource switch, and experience an overall decrease in economic efficiency as a result. For government taxation to be beneficial, policy makers must take into account both intentional and unintentional consequences that may arise.

In addition to policy making, the government also holds the responsibility of providing funding for eco-industrial development projects. According to Heeres et al. (2004), the government is typically the project initiator/commissioner, the project manager, and/or a member of the planning group. Typically, most EIP projects are initiated through distribution of government funded grants (Lowe et al., 1997). van Leeuwen et al. (2003) describes the Dutch government as executioners of planning design and developers of a "road map." This roadmap is "a means to develop an EIP that fits [the regional] landscape, has high standard[s] [for] facilities, and is flexible for future expansion" (van Leeuwen et al., 2003). Furthermore, they must conduct specific administrative duties that are associated with preliminary planning, service provision (e.g., providing funding for infrastructure required by EIP tenants at low or no cost), citizen services, sale and distribution of land leases, promotion of networking between companies to uncover potential symbiotic linkages, and even some consulting services (e.g. the Department of Commerce's Economic Development Administration providing local economic development offices with guidelines and procedures for EIP projects) (Heeres et al., 2004). Martin et al. (1996) and van Leeuwen et al. (2003) describe the local government as providing regional information for potential tenants and investors as well; and communicating information pertaining to regulations, available brownfield site locations, envisioned performance requirements, community labor outlook, and regional virgin resources data.

In some cases (typically in Asia and countries where the private sector is not capable of financing such projects), the local government may decide to set up a public authority to lead the development efforts. Public authorities are very similar to development corporations, except their existence is initiated by the government. Public authorities include members from community organizations but primarily consist of multi-disciplinary personnel from local environmental protection agencies, economic development agencies, "green" design consultants, and industrial park consultants. These authorities serve as an extensive administrative structure for planning, recruitment, construction, environmental management, and maintenance. They play a critical role in cross-industry networking between potential tenant firms and serve to catalyze the exploration of regional symbiotic linkages. In the long run, public authorities cannot guarantee the success of the EIP. To ensure the EIP is upholding industrially ecological principles, the public authority will appoint several of its members to the EIP management board (Koenig, 2005).

2.2.2 – Private Investors and Development Teams

Private investors decide to invest in EIP projects based on the probability of success and the degree of uncertainty and risk involved in the project. Before doing this, they typically consult government agencies, as described in the previous section, for information that will allow them to assess how feasible such a project would be for the region in question. More often than not, private investors will hire a consulting team to conduct the feasibility study and analyze how economically beneficial (to the private investors) and sustainable an EIP could be. In other cases, the investor would accept business proposals or a pro forma (i.e., a document projecting the costs and revenues over the life of the project to determine its economic feasibility) from an EIP development team or the potential tenant firms themselves (Desrochers, 2001).

In the case where the government chooses to participate in an EIP development project, a development “team” would be assembled to actually execute the planned design and development tasks (Lowe et al., 1997). Similar to private investors, development corporations (also known as just “Developers”) put together teams to engage in the EIP design and development process. The development team typically consists of a mix of hired industrial development consultants, members from the relevant government agencies (e.g., local environmental protection and economic development administrations), and members from non-governmental community and business organizations. Development teams typically partake in the strategic planning and decision-making implementation that is required to produce the EIP. To be more specific, they "manage the complex process of acquiring land, managing and planning of feasibility studies, and assembling of investment strategies" (Lowe et al., 1997).

One interesting example of development team practice comes from the Netherlands, where four different development systems are most often executed. The "Eco-classification system" requires that Dutch development teams create a master plan of the EIP in collaboration with other decision-makers (e.g., government agencies, potential tenants, and community leaders) and stakeholders. This plan for development focuses on two groups of themes: themes focusing on how EIP affects its surroundings and themes focusing on construction of the EIP itself. The "Environmental Grading System" instructs Dutch development teams to implement three packages. The first package responds to municipal obligations by meeting environmental requirements presented to them by local regulatory agencies. The obligatory-second package requires development teams to provide individual firms (looking to enter the EIP) with all mandatory criteria for involvement in the EIP. These criteria would be aligned with achieving a beneficial triple bottom line and are derived from requirements the potential tenant firm *must* meet. The non-obligatory third package presents development teams with the opportunity to provide individual firms with additional rules and to suggest product and process innovations. The

"Sustainability Scan" system instructs Dutch development teams to gather information and interview potential tenant firms to assess their realistic carrying capacity and willingness to take action. The research and subsequent interviews help paint a picture of how feasible a potential tenant would be with respect to existing and probable tenants already in the EIP. Similar to the "Sustainability Scan" system, the "Helping Hand" system encourages symbiosis through communication, decision points, and steering roles of each participating actor. This system aims to develop enough carrying capacity (i.e., region's ability to deal with EIP's industrial metabolism) for EIP tenants within five steps: (1) initiation, (2) orientation, (3) decision-making, (4) design and (5) implementation. The last system commonly employed by Dutch development teams is the "Roadmap and Quick-scan" system. Like the name implies, the development team uses a "roadmap" (developed in conjunction with the appropriate government agency as a means to the design and development process) to conduct a "quick-scan." The "quick-scan" was developed so development teams could make a qualitative assessment of an industrial park. Thus, the "quick-scan" serves as the methodology for assessing how a firm would fit into an EIP whose criteria for entry are contained in the "road map." From the preceding Dutch development team examples, it is clear that they are responsible for assessing the firms that plan on entering the EIP; for assessing the carrying capacity of the proposed region; for recruiting tenant firms; and for promoting the EIP concept among community members (van Leeuwen et al., 2003).

2.2.3 – The Community, Non-Governmental Community Organizations, and Educational Institutions

Typically, communities are thought of as a grouping of people that have something in common. There are three types of communities that exist (Tropman et al., 2001):

1. Geographic communities range from local neighborhoods, suburbs, villages, towns or cities, regions, nations and even the planet as a whole. These refer to communities of *location*.
2. Communities of culture range from the local clique, sub-culture, ethnic group, religion, or the global community of cultures. They may be included as *communities of need* or *identity*, such as disabled persons, or the elderly.
3. Community organizations range from informal family or kinship networks, to more formal incorporated associations, political decision-making structures, economic enterprises, or professional associations at a small, national or international scale.

In the context of this thesis, “community” refers to the non-governmental community organizations that proactively represent geographic community members (e.g., the town hall meeting participants), business community members, and the local non-human living organism community. These community organizations can be thought of as the voice of the stakeholders, because they typically collaborate with EIP developers and government agencies (the decision-makers) during the design and development of EIP projects. The decision-makers need to consult with community organizations to learn how community members are reacting to decisions and actions occurring during the EIP design and development process (Martin et al., 1996).

Community organizations are not responsible for funding the EIP project; however, they do hold the power to exercise political routines. These political routines are carried out when the community organization feels its constituents will be negatively impacted by the authorization of a decision and decides to block or mitigate the authorization. This typically leads to bargaining between the community organization and the decision-makers (Mintzberg et al., 1976). Open house or town hall meetings serve as a suitable arena for bargaining to occur, typically resulting in consensus building between decision-makers and stakeholders. Before political interrupts can harm the development process, decision-makers may issue EIP informational packages (highlighting the benefits, drawbacks, principles, and plan of development associated with the EIP project) and surveys directly to community members (or at least community organization members) in order to gain valuable feedback from the community before opposition can form (Lowe, 2001).

Educational institutions play an important research based role in the design and development process of EIPs. These institutions are often sponsored by the state government to conduct research that will produce tools for design and analysis of industrial eco-systems. Faculty and staff from business, engineering, environmental sciences, architecture, and other disciplines could support planning, conduct action research on the project, provide technical and management training, and even provide students for internship or work study programs (i.e., lower cost temporary employees). To support planning, these institutions often conduct feasibility studies to determine what industrial clusters are suitable for the region's proposed EIP. Many partnerships can be formed between tenants and educational institutions that would benefit both organizations. For example, if an EIP recruited a renewable energy tenant, then that tenant could benefit from a partnership with a nearby university by gaining access to the university's body of work in the areas of renewable energy and industrial ecology. This partnership would benefit the university by providing them with a source of renewable energy industry perspective that can help align faculty research focus and current industry needs (Lowe, 2001). Universities can even play a leadership role by forming multi-disciplinary teams that educate industry leaders, community organizations, and contribute directly to research and development efforts. As an example, Nova Scotia's Burnside Industrial Park was initiated by a multi-disciplinary team based at Dalhousie University's School of Resource and Environmental Studies. Another example brings us to Fairfield Eco-Industrial Park in Baltimore, Maryland. The earliest research and development efforts were conducted by Cornell University in conjunction with Baltimore Development Corporation.

2.2.4 – EIP Inhabitants

Prior to entering the EIP, potential tenant firms are responsible for several tasks. Design charrettes are large workshops initiated by community organizations, government agencies, or private sector organizations to address a particular design issue. Potential tenant firms, investors and stakeholders are invited alike. These charrettes are primarily responsible for encouraging agreement on project goals, saving time by collaborating on ideas, issues, and concerns early in the design process (to help avoid costly iterative redesign activities later), and to formally initiate the EIP design process. In addition, the design charrettes introduces industrial ecology to those unfamiliar with it and establishes planning and design actions to be taken by decision-makers (Todd, 2009). Potential firms must participate in design charrettes to gain an early idea as to how entering an EIP would benefit, or harm, the company, and to show an early interest in the project. If tenant criteria have not been developed by the EIP development team yet, then the potential tenant should analyze their business operations to see if they meet (or can feasibly change to meet) tenant criteria. This is an important self assessment that can be carried out by the environmental management system personnel of a potential tenant. While determining if a potential tenant meets the EIP tenant criteria, an analysis to determine whether they should even enter the EIP is conducted, with the firm's best interests guiding the analysis. This analysis is based on symbiotic compatibility with other finalized tenant firms (or, more generally, the prominent industrial sectors represented at the design charrette), existing industrial-scale production regulations and ordinances, the anticipated financial burden, and any anticipated risks and uncertainties (and their associated magnitude). The next task potential tenants are faced with, is providing operational requirement information to the EIP development team. Potential tenants must be careful not to divulge proprietary information to industry competitors while reporting production system characteristics and requirements. (Lowe et al., 1997).

Once a tenant firm has been given a lease and the permission to operate within the EIP, several more responsibilities arise. The tenant firm must provide funds for facility construction on land they have selected to lease. If the tenant doesn't have enough capital to fund land leasing and construction, then investors can be solicited to help cover these costs. If infrastructure is not paid for by the government, then tenant firm needs to collaborate with neighboring tenant firms as to who will pay for each required structural element and to determine an overall infrastructure construction plan. Before construction of facilities and infrastructure can initiate, tenant firms need to determine what changes to their operations and production processes are required to ensure symbiotic compatibility with neighboring firms and the surrounding community. This is typically done in collaboration with the neighbors the tenant firm intends on entering bilateral agreements with (Koenig, 2005). On a higher level, tenant firms must collaborate with the EIP development team on action points contained in the master plan. The master plan is created by the development team and describes the layout design of the EIP, the involved partnerships, the site architecture, landscape design, vegetation distribution (also called “plant palette”), signage, lighting, site amenities, and EIP transportation and circulation (Potts-Carr, 1998). In the long term, each tenant must ensure that there is room for growth for their company. This typically requires building co-owned warehousing or storage units, purchasing more land than needed initially, and continually looking for new byproduct exchange opportunities. New byproduct exchanges should always be searched for in case existing neighbors move away or decide to change their production scheme that would, in the process, eliminate a byproduct supply flow (into the tenant) or a byproduct demand flow (out from the tenant) that existed before. Considering the surrounding community, a loss in demand for the tenant’s products or services or an interruption in the flow of reusable waste into the tenant could lead to an increase in input resource costs (Nolan, 2004).

Once the development team is finished with its design, development, and implementation tasks, it is time for an EIP management board to be formed. As mentioned earlier, this board typically consists of government agency members, development team members, and a capable manager from each EIP tenant. During the EIP development process, the management board is responsible for the tasks listed in Table 2.

Table 2: Responsibilities of EIP Management Board (UNEP, 1996)

1. Planning	• identify possible sites
	• conduct environmental impact assessments
	• select sites (from pool of potential greenfield and brownfield site alternatives)
	• undertake pre-planning
	• present conceptual design layouts and decide which layout fits the community, environment, and neighboring companies best
	• develop an environmental policy and set environmental performance objectives
	• locate sources of funding to finance the project
	• attract industry leaders who have ability to invest in byproduct exchange projects with other symbiotic industrial leaders
2. Operating	• manage construction of infrastructure and services (in cooperation with contractors and EIP inhabitants)
	• coordinate operation of infrastructure and services between EIP inhabitants
	• design individual facility sites
	• construct facilities
	• landscape sites
	• market environmental quality to ensure that all EIP participants are aware of expectations, to ease the community about how EIP will impact them, and to make community more aware of how it can contribute to resource reuse, recycling, and recovery
	• transport of goods, materials, and people
	• facilitating networks between companies within and outside of EIP
3. Control	• monitor rate of emissions and media quality
	• motivate tenants to perform for environmental achievement and provide incentives for positive results
	• enforce regulations or covenants
	• audit environmental performance
	• report on environmental performance of companies and park
	• attend to common safety issues and ensure the facilities are safe to conduct business in.

	• establish a regulatory framework (e.g., codes, covenants, and restrictions)

No matter how talented the EIP management board is, there is little hope for proper development of an EIP that will improve a region's triple bottom line without the determination of a set of EIP project deliverables early by EIP developers. These deliverables should overlap significantly with what the stakeholders and decision makers consider to be important objectives of the EIP project. Some standard deliverables from EIP design and development projects include (but are not limited to) the following (van Beers, 2008):

- Industrial Ecology Feasibility Analysis (of the region in question): Takes into account and clearly define the resource pool of the region, the existing business makeup (ranging from small business to industrial scale production centers), potential regulatory drawbacks, and potential for by-product, energy, water, or other ecologically-friendly symbiotic exchanges;
- Action Plan: Acknowledges challenges, notes benefits, creates initial estimates (for land required and cost of infrastructure, utilities, etc.), and mentions possible sources of funding and why those entities would be interested (e.g. ROI, regional economic revitalization, job creation, environmental waste reduction, etc.). Also highlights roles and responsibilities of decision makers in the project;
- Symbiosis Network (web-based): Public (or by registration to preserve companies' valuable production information) disclosure of available byproduct materials, available alternative or recovered energy, non-potable water, or any other items or "waste" that may be considered for a symbiotic

exchange. May be organized with respect to industry, business type, needed byproducts, or by byproducts that would need to be donated or sold;

- Improvements to infrastructure nearby EIP site; and
- Introduction of new, lower cost, and less environmentally harmful utilities or services that would be provided by new EIP tenants (depending on what organizations and businesses enter the EIP).

2.3 – Important Objectives of EIP Development Projects

Typically, businesses advertise their concern for society and the environment in order to increase their customer base. This advertisement attracts environmentally-conscious customers who prefer companies that abide by the "recycle, reduce and reuse" ideology and expect the companies they do business with to do the same (U.S. EPA, 2010). In today's world, sustainable development is beginning to gain more attention because resources (both renewable and non-renewable) are being used at a rate proportional to global population growth. Since the global population is growing, the consumption rate of non-renewable resources will increase and, in addition, the consumption rate of renewable resources may outpace the generation rate of renewable resources (Nassos, 2010). With an increase in resource consumption rate, the cost of these resources will increase as well, especially where scarcities appear first. A current example of this can be seen in the European automobile industry. Compact vehicles that consume less fuel are gaining popularity because the cost of fuel (which is dependent on the availability of oil) is increasing higher than it is in other countries (like the United States) where the cost of fuel is not as high. This increase in the cost of resources will only hurt the economic bottom line of companies reliant on those resources and, on a macro-level, the communities that have to pay higher prices for the same products or services. Thus, to continue successful growth of their business, companies reliant on physical-resources (e.g., small, medium, and large size manufacturers, chemical producers, building materials producers, and other resource intensive industries) must determine what measures will yield the most efficient use of the available resources and ensure that these resources will still be available in the future.

The practice of sustainable development is one way to combat the increasing resource scarcity problem. As mentioned in the Introduction, sustainable development ensures the well-being of present communities (both human, and non-human), without harming the benefits of future communities and the environment. One way to measure how sustainable business operations are is to use the triple bottom line accounting methodology. It is one of many accounting measures that considers the "…simultaneous pursuit of economic prosperity, environmental quality and social equity" as goals for a given organization (Elkington, 1998). The metrics used to measure value for each particular entity are not always obvious, but they need to divulge how the EIP is achieving its fundamental objectives and maximizing the triple bottom line. Money flow fluctuations (recorded in company income statements, balance sheets and cash flow sheets) can describe how the EIP is maximizing its economic bottom line, but it is up to the EIP tenant management to determine suitable societal and environmental measures of effectiveness that will portray a maximized bottom line.

Environmental measures of effectiveness can be found by looking at the physical and biological effects on the environment (like waste disposal rate, or resource consumption rate); however, there is some difficulty in determining the boundary of the industrial system. Environmental measures of effectiveness need to measure how much:

- water is being reused by the EIP (over a given amount of time);
- water is being disposed of by the EIP;
- greenhouse gas is being emitted from the EIP and not being captured;
- greenhouse gas is being reused by other tenants or community members adjacent to the EIP;
- waste material is being terminally disposed of by EIP tenants.

Societal benefits and impacts can be measured by considering the stakeholders (people in the surrounding communities, business communities and others directly or indirectly affected by the industrial system in question). An increase in tax base to the region, newly created high-skill level jobs, increase in traffic to complementary industries, re-growth of renewable resources (or revived public property), decreases in utilization of local landfills, and similar measures can all be considered as useful indicators for increasing social equity (Gertler, 1995).

In order to assess how well a particular EIP development project will perform with respect to maximizing a region's TBL, the objectives of the EIP development decisions must be analyzed for alignment with the TBL objectives. To do this, a rubric was created to categorize and score the objectives of decisions made by EIP development teams during EIP development projects. Each decision objective in the EIP development process is evaluated with respect to two criteria: (1) their performance with respect to four attributes (which results in a "grade") and (2) how equally the decision's objectives attempt to advance the TBL's three high-level fundamental objectives. These criteria and the rubric will be discussed in full within section 3.4. The TBL's objectives (i.e., means, low-level fundamental and high-level fundamental objectives) are connected with respect to how they are advanced or being advanced by others. The means-objectives are objectives that help achieve other objectives (either other means-objectives or fundamental objectives), where as fundamental-objectives are objectives that are important because they reflect what really needs to be accomplished (March and Simon, 1958). The connections are represented by lines connecting the objectives. The many different means-objective chains and can be seen in Figure 12 through Figure 15.

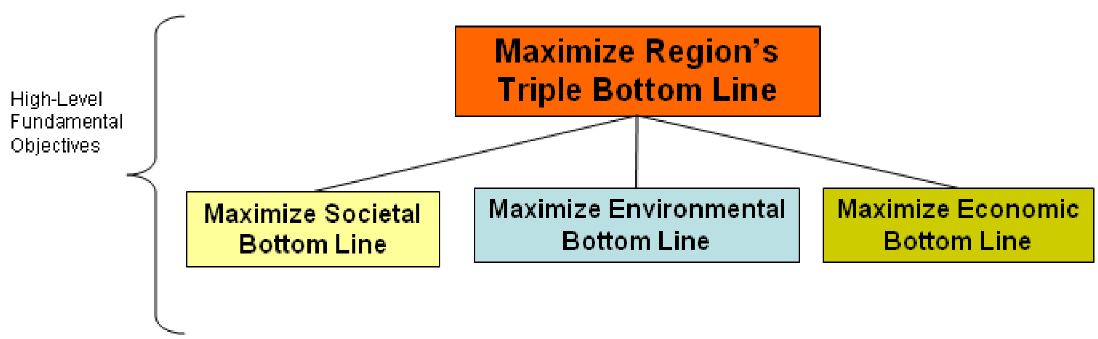


Figure 12: TBL's high-level fundamental objectives

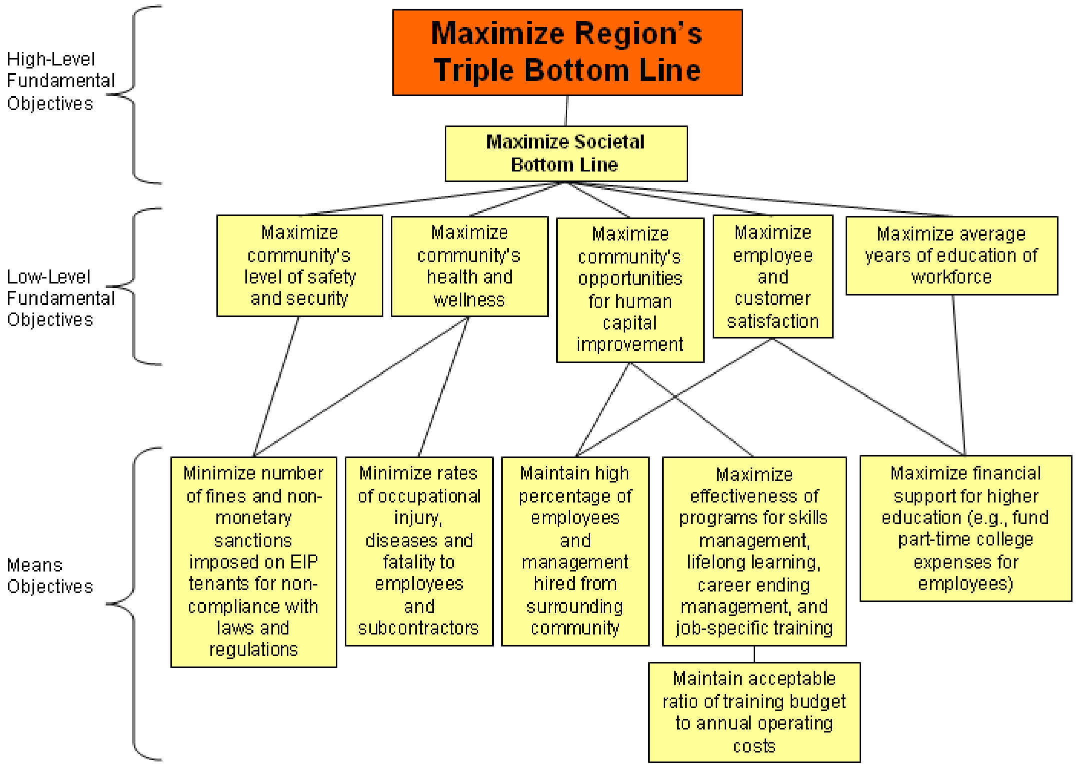


Figure 13: TBL's objectives that contribute to the societal bottom line

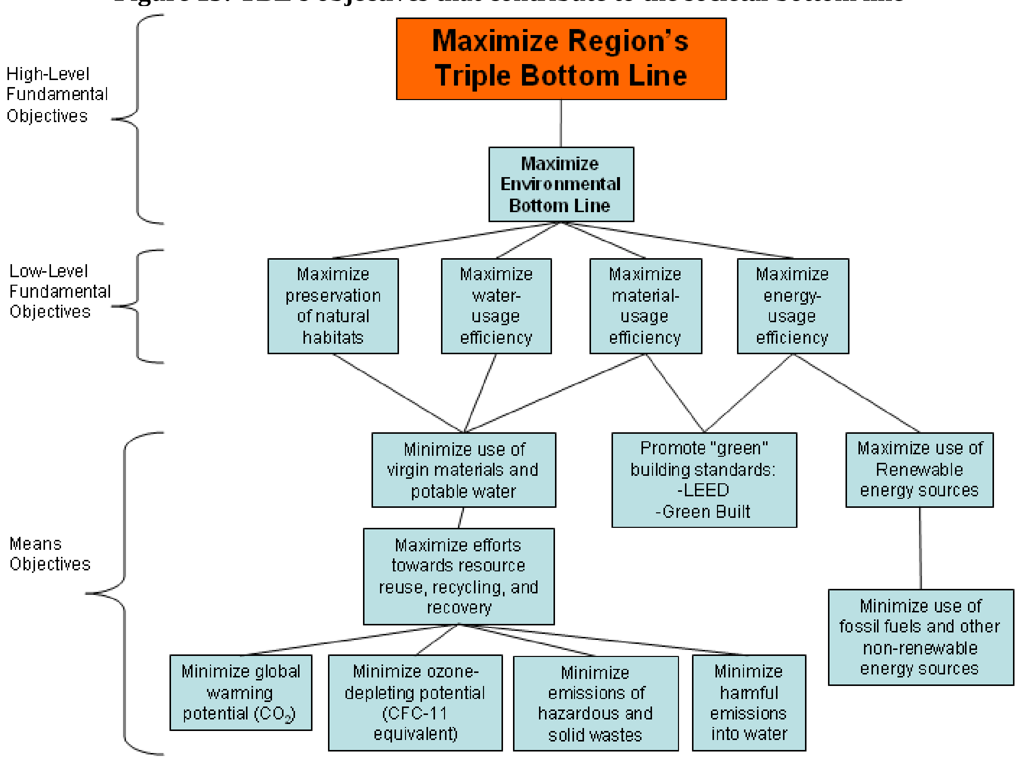


Figure 14: TBL's objectives that contribute to the environmental bottom line

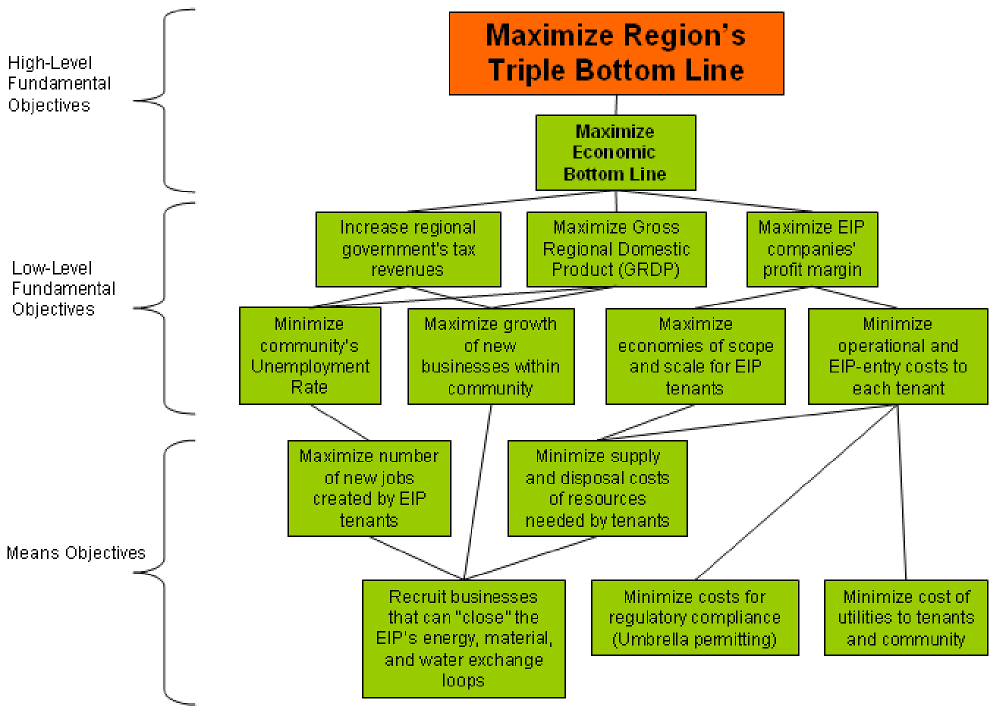


Figure 15: TBL's objectives that contribute to the economic bottom line

The objectives in Figures 13, 14, and 15 list different means to maximizing the triple bottom line. The EIP development team must generate EIP project goals and initiatives that will maximize the triple bottom line of the region in question, not just their own financial bottom line. This means that the objectives of the EIP focus on maximizing benefit to the environment, society, and the regional economy. An EIP can serve to enhance benefits for its inhabitants, society, and the environment, thus, ensuring sustainable development of the region in question.

2.4 – Analysis of EIP Development Processes

2.4.1 – The Structured Decision Process

The structured decision process identified by Mintzberg et al. (1976) consists of twelve elements: three central phases (i.e., identification, development, and selection), three sets of supporting routines (i.e., decision control routines, design communication routines, and political routines), and six sets of dynamic factors that help explain the relationship among the central and supporting routines (i.e., interrupts, scheduling delays, timing delays and speedups, feedback delays, comprehension cycles [i.e., learning that occurs with respect to the decision-making problem's constraints, requirements, alternatives, and other information after multiple iterations of the design, search, screening, or evaluation of choice routines are experienced], and failure recycles). This paper conducted an excellent study that utilized graduate student teams to conduct interviews with decision-makers within 25 different organizations. The decision-makers answered 21 questions (either during the decision-making process or toward the end of it) that were intended to comprehensively define the "unstructured" decision process that they conducted (Mintzberg et al., 1976). Mintzberg et al. (1976) defines a *decision* as a specific commitment to action (e.g., resource allocation) and defines a *decision process* as a set of actions and dynamic factors that begins with the identification of a stimulus for action and ends with the specific commitment to action. In addition, it is important to note that Mintzberg et al. (1976) defines an *unstructured* decision process as a process that has not been encountered in quite the same way by the organization in question. This implies that the organization conducting an unstructured decision process will not have a predetermined set of ordered responses (e.g. a set of heuristics to help solve a commonly faced production problem) and that they will be making a decision under ambiguity (where almost nothing is given or easily determined at the onset of the decision process). For the sake of time, each of these elements will not be discussed here, but how they relate can be seen in Figure 16. With respect to eco-industrial development, the stimulus is typically of the opportunity type because the EIP project initiators are not acting under intense pressures (i.e., when a “crisis” stimulus arises); instead, they’re attempting to improve a situation that could be improved.

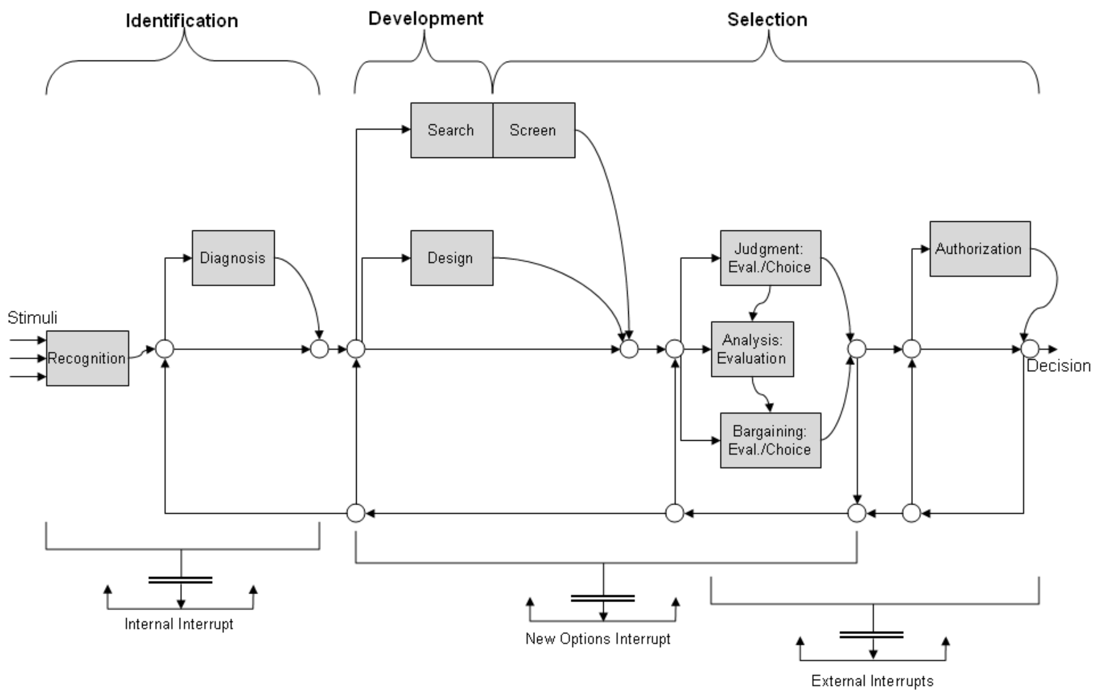


Figure 16: Structure of General Decision-Making Process (Mintzberg et al., 1976)

The top portion of Figure 16 identifies the primary phases: identification, development, and selection. Each shaded block in Figure 16 represents a routine carried out by the decision-makers, while the straight arrows represent the transition to a new routine within the process. The curved arrows represent inherent delays that occur after a routine; these include scheduling, feedback, and timing delays. Each circular node separating transitions between routines represents a decision that needs to be made to determine the next course of action (i.e., a meta-decision), and are based on available information, potential for interrupts, overall time to complete entire decision process, and authorizations or permissions that may be required before selecting and moving on to the next routine. Mintzberg et al. (1976) uses the 12 elements of structured decision-making to differentiate the 25 examined strategic decision processes and place them into the following seven categories (also referred to as strategic decision types):

1) Simple impasse decision processes – begins with recognition (triggered by stimuli); followed by diagnosis; some internal interrupts, and the evaluation and selection of choices.
2) Political design decision process – begins with recognition, followed by diagnosis, design of solution, political interrupts (internal or external), and evaluation of choices. Political interruptions lead to more redesign (to counter political interruptions). Evaluation of Choices, after redesign, is required, so the analysis and bargaining routines are performed extensively before a selection is made.
3) Basic search decision process – begins with recognition, followed by search. Search typically contains one or two nested steps; search flowing into the evaluation of choices routine followed by continued search). Some interrupts typically occur, so the selection of phase involves the analysis and bargaining routines. This process concludes with the selection routine.
4) Modified search decision process – this process includes development activity that requires modifications (limited design activities) to ready-

made alternatives (e.g. retrofitting or remanufacturing). The process begins with the recognition routine, followed by design, evaluation of choices, search for more choices, further evaluation of choices (i.e., nested iteration between search, design, and evaluation of choices (or, just "nested design")), and finally authorization.

5) Basic Design Decision Processes (marketing) – this process focuses on extensive design activity that leads to complex and innovative custom-made solutions (e.g. EIP development projects). This process is usually observed when opportunities or relatively mild problems arise. The process is of short duration with no political interference – commercial decisions taken by business or business-like, organizations; measurable factors of profit clearly out-weight political considerations. Typically, this process begins with recognition, followed by design, evaluation of choices, nested design, and finally ending with authorization.

6) Blocked design decision processes (public works) – this decision process is similar to basic design decision processes, except final stages (selection phase) are hindered by outside groups (e.g., community groups demonstrating opposition to a public or private development project that they believe will have negative impacts on their community). The selection phase would typically include analysis and bargaining routines (in an iterative manner) so decision-

makers can form consensus with the opposing stakeholders. This process would then conclude with the authorization routine.

7) Dynamic Design decision processes (facilities) – these decision processes are the most complicated. They typically encounter multiple interrupts, usually of the problem or problem-crisis type (i.e., unpredictable and potentially detrimental to the project), and last roughly 1 to 4 years. The dynamic nature of these facilities' decisions reflects (a) the relatively large investment needed, (b) the complex design activity involved in such facilities, and, paradoxically, (c) the likelihood of new option interrupts because of the availability of ready-made structures (e.g. brownfield sites, facility layouts, building material availability, etc.). This decision process typically involves recognition, design, evaluation of choice, interrupts (internal and/or external), and further nested evaluation of choice (with, judgment, analysis, and bargaining routines being exercised heavily). The evaluation of choice routine is followed by more design, and search routines, or flows into the authorization routine. All nested activities occur in reaction or in anticipation of interrupts.

Mintzberg et al. (1976) shows that any unstructured decision-making process can be classified as one of these seven types of decision-making processes. It is important to realize that these categories were constructed from synthesis of the 12 elements contained in the general decision process (or strategic decision process); these elements serve as the building blocks to the general decision process. By using the same approach employed by the graduate teams in Mintzberg et al. (1976), the 12 elements (or at least the six routines) of their general decision process can be used to categorize the decisions made during the EIP design and development processes.

2.4.2 – The 21 EIP Development Processes and the Structured Decision Process

The EIP development process, the parties involved, and the objectives of EIP projects have been described up to this point. Now, it is time to focus more on the design and development process used by development teams to bring EIP projects into the implementation phase. Research was conducted to identify 21 EIPs. Next, was the documentation of the development processes belonging to the 21 EIPs worldwide and in the U.S.. The documents that were studied include informational brochures (attempting to market EIPs), presentations given by EIP developers, feasibility studies, journal articles that analyze EIP development projects, journal articles that present and analyze EIP case studies, government publications (that included everything from guidelines to EIP development to case studies around the world), news articles, and websites advertising specific EIP development projects. The properties of these 21 EIP projects are summarized in the tables below. Table 3 states where the EIP development project takes place and Table 4 explains the participant decision making entities for each EIP project.

Table 3: 21 EIP projects studied and their locations (EIP Design Process #1 courtesy of: (Nolan, 2004). EIP Design Process #2 courtesy of: (Lowe, 1997).EIP Design Process #3 courtesy of: (Wasserman, 2001). EIP Design Process #4 courtesy of: (Koenig, 2005).)

EIP Design Process #	Location of EIP (Region, Country)
1	None; Process from presentation at the Eco-Industrial Network Roundtable (Vancouver, BC - Canada)
2	None - this is a general EIP development process - USA & Asia
3	None, purely theoretical; Design Process used in Masters Thesis - USA
4	State Environmental Protection Administration (SEPA) list of Approved Projects (12 in all) - CHINA
5	Saint Peter, Minnesota - USA
6	Perry County, Illinois - USA
7	Gulf of Mexico Region - U.S./Mexico collaboration
8	Devens, MA - USA
9	Hinton, Alberta - Canada
10	Fort McMurray, Alberta - Canada
11	Delta, British Columbia - Canada
12	Regina, Saskatchewan - Canada
13	Research Triangle Region with two designated areas (Person-Granville-Vance-Warren-Franklin Counties area & Chatham-Moore-Lee-Harnett Counties area) North Carolina - USA
14	Rantasalami, Finland
15	Mecca, California - USA
16	Daedeok Techno Valley, Daejeon City - South Korea
17	Northampton County, Virginia - USA
18	5 Pilot sites all over country of Thailand
19	Port of Columbia, Dayton, Washington (state) - USA
20	South Los Angeles, California - USA
21	Santa Cruz County, California - USA

Table 4: 21 studied EIP projects and the decision makers leading their development

EIP Design Process #	Decision Making Entities
1	Community, EID team, local/potential/involved businesses, regulatory agencies
2	Organizing Team (Industrial Development Authority if gov't initiates; Development Corporation otherwise), Tenants, Personnel from Environmental Protection, local Universities, and Economic Development Agencies, Recruiters, Investment Recovery Specialists, Multi-disciplinary consulting organizations
3	Developers, Architects, Landscape Architects, Construction Managers, Firm (tenant) Mgmt, Local and State Gov't (economic and environmental dept.s), EIP mgmt entity, University IE research centers, Private sector brokering or scavenger firms, private firms (consultants)
4	EIP Planning Office (Team Leader/Director), Municipal Sustainable Dev. Pilot Region Mgmt Office (Registered Planner and vice team leader), Municipal Environmental Protection Bureau (EPB) (Senior Engineer), Municipal Planning Bureau (Registered Planner), EIP EPB (Manager), EIP Economic Development Bureau (EDB) (Vice Manager), EIP Planning and Construction Mgmt Office (Specialized Consultants/Contractors), EIP Planning Academy, Professional Technology School (Vice Dean), Representative engineers and mgmt from tenants
5	Saint Peter Community Development Corporation, Saint Peter Ambassadors (Community representatives), Saint Peter Chamber of Commerce, NRG Inc. (a private energy provider), Minnesota Office of Environmental Assistance, The City of St. Peters, and a newly created EID Advisory Committee/Board
6	University of California Center for Economic Development, National Center for Eco-Industrial Development (NCEID), GERE Properties Inc. (builders of materials recovery facility), Perry Ridge Landfill Inc., Perry County, Union Pacific Corporation (rail lines for transloading operation), Illinois EPA Administrative Region Seven NOTE: The report primarily focused on potential regional tenants, business partners, and very few gov't organizations since it was a feasibility study focusing on the byproduct exchanges and financing
7	Businesses, community leaders, government agencies (e.g. the Business Council for Sustainable Development - Gulf of Mexico (BCSD-GM), EPA, World Business Council for Sustainable Development (WBCSD), trade organizations, etc.), consulting firms,
8	Devens Enterprise Commission (12 elected member volunteers from community) (DEC), Towns of Ayer, Harvard, Lancaster, and Shirley, Massachusetts Government Land Bank, Division of Capital Planning and Operations (DCPO), Joint Boards of Selectmen (from the 4 participating towns), Land Use Administrator (appointed by DEC), Involved/Perspective Tenants
9	FCM Green Municipal Funds, Town mayor and council (Town of Hinton Council), planning & engineering staff (e.g. Development Officer and Municipal Planning Commission), Local Environmental Groups, Local

	industry representatives, Herold Development Services Ltd (so called Development Authority), Holland Barrs Planning Group, Western Economic Diversification, Climate Change Central
10	Wood Buffalo Housing and Development Corporation, Eco-Industrial Solutions Ltd, Regional Municipality of Wood Buffalo (RMWB), Dillon Consulting Ltd, Natural Resources Canada (funding), TD - Alberta Commercial Banking Group, Business Development Bank of Canada
11	EIN members: BC Hydro, Burns Bog Conservation Society, CAPTIN, Delta Chamber of Commerce, Delta Recycling Society (DRS) Earthwise, Fraser Basin Council, the Greater Vancouver Regional District, Nature's Path Foods, Pistol & Burnes, Taylor Munro Energy Systems, Terasen Gas Inc., The Corporation of Delta, West Bay Son Ship Yachts, the Eco-Industrial Group, and Schenker Pacific Logistics
12	Ross Businesses (currently 500 businesses in existing industrial park), City of Regina, Regina Eco-Industrial Networking Association (REINA), Transport Canada – Moving on Sustainable Transportation (funding), Regina-based Communities of Tomorrow - Partners for Sustainability (funding), Saskatchewan Environment, and the University of Regina
13	Golden LEAF, Research Triangle Regional Partnership, University of North Carolina at Chapel Hill (Office of Economic Development), Kerr-Tar (Northern Tier) Council of Governments, Department of Commerce, Industrial leaders in region, General Assembly, EPA, U.S. Economic Development Administration, and the Governor's Economic Development Board
14	Regional Council of Etelä-Savo, Rejlers Oy Engineering (project lead and EIP coordinator until July 2007), Real Estate Rantasalmen Silva Oy {(manages and maintains the land and premises and acts as a development company in the region) (owned by Rantasalmi municipality (49%), Rantasalmi Oy (49%) and Spikera Oy (2%))}, Rantasalmi Oy (loghouse mfg), Sil-Kas Oy (wood processing company), Korpihonka (wood product company), Raitaranta (carpentry company), Myllys Ky (family company providing transport and forklift truck services; maintains local wood drier), JK-Terämet Ky (regional blade maintenance), and Kanttiini Seija Partinen (restaurant)
15	Colmac Energy, Inc. (a biomass-fueled power generation plant). First Nation Recovery Inc. (a crumb rubber manufacturer from old tires), Non-Profit Development and Park management (w/ board of directors from tenant businesses), Public Agencies (EPA, economic development department, City, etc.), Cabazon Band of Mission Indians (landowners; Planning Department carries out actions),
16	Daejeon Metropolitan City (administrative support), Hanwha Group (management support and operation of support programs for tenants), Korea Development Bank (financial support)
17	Northampton County, Community (non-profit committee or council members), Official Planning Team (consists of: designers, architects and engineers; federal, state, and local government regulatory and support agencies; public and private potential investors; potential corporate tenants)
18	Industrial Estate Authority of Thailand (IEAT) (envisions projects that incorporate by-product exchange, resource recovery, cleaner production, community programs and the development of eco-industrial networks) , German Technical Co-operation Organization (GTZ) (assists through technical transfer and policy development), Department of Industrial Works (helps w/ policy and regulation), Ministry of Science, Technology and the Environment (helps w/ policy and regulation), current estate tenants (from 5

	pilot industrial parks)
19	State of Washington (Washington State Department of Transportation, Washington State Community Economic Revitalization Board), Port of Columbia (Columbia County), Pacific Power, City of Dayton, USKH Architecture and Engineering firm, and potential tenants
20	Community Redevelopment Agency, the City of Los Angeles (Community Planning Bureau), the County of Los Angeles, Community Stakeholders (Hyde Park Organization for Empowerment, Park Mesa Heights Community Council, View Park Community Association, Hyde Park Community Advisory Committee, Los Angeles Neighborhood Initiative (LANI), and other neighborhood councils), Private Developers, a Community Development Corporation (such as West Angeles CDC), Hyde Park Merchants Association, Economic Development Administration
21	Santa Cruz County (Board of Supervisors and staff within Department of Public Works, and Planning Dept.), HDR/Brown, Vence and Associates (HDR/BVA), Monterey Regional Waste Management District (MRWMD). *** Considering waste transfer station in 2008, but EIP as a whole deemed not feasible in mid-2009 by Board of Supervisors ***

We rely upon the findings of Mintzberg et al. (1976) for the analyses. First, the decisions used in each of the EIP development processes are categorized by the type of Mintzberg et al. (1976) routine they are. Then, the EIP development process itself is categorized by process type, project initiating stimuli, and solution characteristics.

2.4.3 - Micro-analysis: Classification of EIP Development Process Decisions with Respect to Mintzberg et al. (1976) Routines

Even though the decisions made during EIP design and development processes are not always clearly presented, documented action items and plans for the future can be used to implicitly determine the EIP design and development decision-makers and their respective decisions. Once the development process used to develop each EIP was determined, each individual decision is categorized by the structured decision process phase (i.e. identification, development, or selection) during which it would occur, and then carefully matched with its corresponding routine. Table 5 demonstrates each of the 21 EIP development processes studied and how they are classified with respect to the routines of Mintzberg et al. (1976).

Table 5: Categorizing of EIP Development Processes with respect to Strategic Decision Process' Routines (Template courtesy of Mintzberg et al. (1976))

EIP Design Process #	Number of Mintzberg et al Decision Steps/Routines Reported					
	Identification Phase		Development Phase		Selection Phase	
	Recognition	Diagnosis	Search	Design	Eval. Choice	Authoriz.
1	1	4	3	6	1	1
2	4	7	4	5	2	1
3	1	3	3	4	3	2
4	3	6	7	5	3	2
5	2	6	9	2	4	3
6	2	6	5	4	2	1
7	4	9	5	1	4	2
8	2	4	3	3	4	2
9	2	7	2	7	5	3
10	3	3	4	10	1	5
11	2	3	2	0	0	0
12	1	3	4	2	4	3
13	1	4	3	3	6	4
14	2	4	4	8	3	5
15	1	5	3	2	5	3
16	1	7	3	9	6	7
17	2	3	5	4	4	4
18	1	5	2	3	3	1
19	1	4	1	8	4	3
20	3	9	8	12	6	10
21	3	9	3	3	6	6
TOTALS:	42	111	83	101	76	68
AVERAGES:	2.0	5.3	4.0	4.8	3.6	3.2

Each row represents a different EIP design process. Each column to the right of column one represents distinct decision process routine categories (which each belong to one of the three decision process phases). Each time an EIP design process achieves a step within their process, it is carefully categorized as one (or more) of the six types of routines. Each number (other than those in column one) in Table 8 represents the number of times a reported step within a given EIP design process performs the routine it is categorized under. In some cases, a reported step may be categorized under more than one routine, and, in even more rare cases (where the step is very involved), a EIP design process step may cross over more than one Mintzberg et. al phase. As a general example, if an EIP development team reports conducting a feasibility study of the region in question, then that activity would first be categorized into the identification phase because it deals with identifying the decision-making problem. Afterward, the feasibility study activity can be categorized as a diagnosis routine because the characteristics of conducting a feasibility study (i.e., the gathering of information, determining the root of the problem, identifying what needs to be corrected or improved, and determining whether it can be achieved with the resources and technology available) match the characteristics of a diagnosis routine (i.e., identifying the problem or opportunity for improvement and gathering information about it to further clarify it) (Mintzberg et al., 1976).

2.4.4 - Macro-analysis: Classification of EIP Development Processes with Respect to Mintzberg et al. (1976) Strategic Decision Types, Stimuli, and Solution

Once each EIP design and development process has been decomposed into a series of decisions which were then categorized into the strategic decision process routines, it is time to take a new perspective and consider what types of decision processes the EIP development processes are. This information may be helpful in the future by providing a searchable set of classifiers that categorize the different types of EIP design and development processes by (1) their associated stimuli, (2) the type of solution, and (3) the type of decision process observed (with respect to the seven types of processes identified earlier).

The initial set of decision classifications depend on the type of stimuli that is received by the decision-maker(s). Stimuli generally occur during the recognition routine. The stimulus is how the need for a decision gets recognized by decision-makers and sets the tone for the decision process ahead. An opportunity decision is the most optimistic of the three classified by stimuli; it is initiated on a purely voluntary basis with intentions of improving an already secure situation (e.g., the introduction of a new product). A crisis decision is initiated by stimuli that carry intense pressures with it and require immediate attention. An example of this type of decision stimulus would be a fire or a bankruptcy. The last type of decision categorized by stimuli is a problem decision. These stimuli are less severe than crisis stimuli, and typically require more than one problem stimulus before the recognition routine can begin. It is typically at the decision-makers' discretion as to whether a problem decision needs to be addressed within a reasonable time frame, or even at all (Mintzberg et al., 1976).

The second set of decision classifications depends on the type of solution that the decision-makers choose. The least likely solution to be found by EIP development teams is the given decision solution. This occurs when the solution is already fully developed at the start of the process. The second type of solution decision is a ready-made decision solution. The ready-made solution is fully developed in the environment. An example of this type of solution would be the purchasing of an aircraft that is already designed and built; no modification will be done to the aircraft before it is put to use. The third type of decision solution is a custom-made solution. Custom-made solutions are those that are developed specifically for the decision at hand. For example, construction of a new headquarters building would only satisfy that particular “need for new headquarters” decision process, but if that same company wanted to build a new factory, this decision process would be different because the building requirements and functions are fairly different. The last type of decision solution is a modified solution. These solutions are a combination between ready-made solutions and custom-made solutions. These solutions contain ready-made components that are modified to fit the particular situation or design. An example of this would be a solution that requires retrofitting of a facility’s combustion exhaust system (using known technology that needs to be modified to interface properly with the plant’s equipment) to reduce carbon dioxide emissions into the atmosphere (Mintzberg et al., 1976).

The third set of decision classifications depends on the type of decision process used to arrive at the solution found or developed (i.e. which strategic decision process best approximates the decision process in question). This can be determined once the decision process has been completed and the decisions have been categorized by their associated routines. The decision process in question can be classified by identifying which of the seven decision process types contains the same ordering of its routines as the design process in question (i.e., ask which of the Mintzberg et al. strategic decision processes contains routines most closely correlates with the EIP decision process in question’s development steps) (Mintzberg et al., 1976). Please refer to the list of strategic decision types presented earlier in this section.

With each type of decision classification defined, the 21 EIP development processes studied can be categorized. An example of an EIP development process being categorized in terms of the strategic decision process's routines can be seen in Table 42 of the Appendix. This categorizing is repeated for each of the 21 EIP development processes and used to determine what type of decision process they are. A summary of the categorizing of each EIP design process is summarized in Table 6.

Table 6: EIP design processes categorized with respect to Mintzberg et al.'s decision process types (i.e., type of stimuli, process type, and solution type).

EIP Design Process #	Type of Decision Process		
	By Stimuli	By Process	By Solution
1	Opportunity	Dynamic Design	Modified
2	Opportunity	Dynamic Design	Modified
3	Opportunity	Dynamic Design	Modified
4	Opportunity	Dynamic Design	Modified
5	Opportunity	Dynamic Design	Modified
6	Opportunity	Dynamic Design	Modified
7	Opportunity	Dynamic Design	Modified
8	Opportunity	Dynamic Design	Modified
9	Opportunity	Dynamic Design	Modified
10	Opportunity	Dynamic Design	Modified
11	Opportunity	Dynamic Design	Modified
12	Opportunity	Dynamic Design	Modified
13	Opportunity	Dynamic Design	Modified
14	Opportunity	Dynamic Design	Modified
15	Opportunity	Dynamic Design	Modified
16	Opportunity	Dynamic Design	Modified
17	Opportunity	Dynamic Design	Modified
18	Opportunity	Dynamic Design	Modified
19	Opportunity	Dynamic Design	Modified
20	Opportunity	Dynamic Design	Modified
21	Problem	Dynamic Design	Modified

From this analysis, it is clear that most EIP design and development projects:

1. Are opportunity problems (after categorizing by stimuli);
2. Require a dynamic design decision process (after categorizing by decision process); and
3. Lead to the development of a modified solution (after categorizing by solution type).

The classifications of 21 EIP development decision processes has led to the conclusion that most of these decision processes belong to the same three categories (i.e. opportunity problem requiring a dynamic design decision process and resulting in a modified solution) and, thus, can be approached, from a decision process standpoint, in the same manner. The only special case out of these 21 EIP development processes is EIPDP #21. EIPDP #21 has a “problem” stimulus instead of the typical “opportunity” stimulus because the Santa Cruz County Officials (namely, the Monterey Regional Waste Management District Board of Directors) identified their current landfill, the Buena Vista Landfill, as both aging and nearing capacity. Their aims were to create a byproduct-exchanging Zero-Waste Eco-Park where the initial development would be a conversion technology facility, but, in mid-2009, the Eco-Park was deemed infeasible due to a lack of public and private funding (ZBS Radio (2008), Laska (2009)). Even with a differing decision process stimulus, all 21 of the studied EIP development processes will be revisited to create the Revised EIP Development Process (the REIPDP).

2.4.5 - Analysis of how Decisions in Studied EIP Development Processes Lack Consistency with the Triple Bottom Line

To be considered a sustainable development project, the developers need to include representatives from the regional community, environmental organizations, and local industry leaders and make sure to meet each of their needs without compromising another's. A sustainable development project will be consistent with the maximization of a region's triple bottom line if the EIP development team follows a development plan that addresses all three of the TBL's high level fundamental-objectives. In the 21 EIP development processes studied, this is not always the case. To analyze the 21 EIP development processes, a fundamental and means-objective network was created for each project to determine which steps (i.e., means) are actually contributing to a beneficial triple bottom line (i.e., the objective), and which ones do not. These fundamental and means-objective networks were created based on the careful study of the documents describing each EIP's development process.

The means-objective network consists of means objectives and one (or more) fundamental objective. The fundamental objective is the goal of the project or process and can also be referred to as the ends. The means objectives are the ways that a given project or process will utilize in order to try to achieve the fundamental objective. A chain of means objectives demonstrates how the means objectives connect with one another in a combined effort to advance the fundamental objective. An example of a means objective network can be seen in Figure 17 (Clemen and Reilly, 2001).

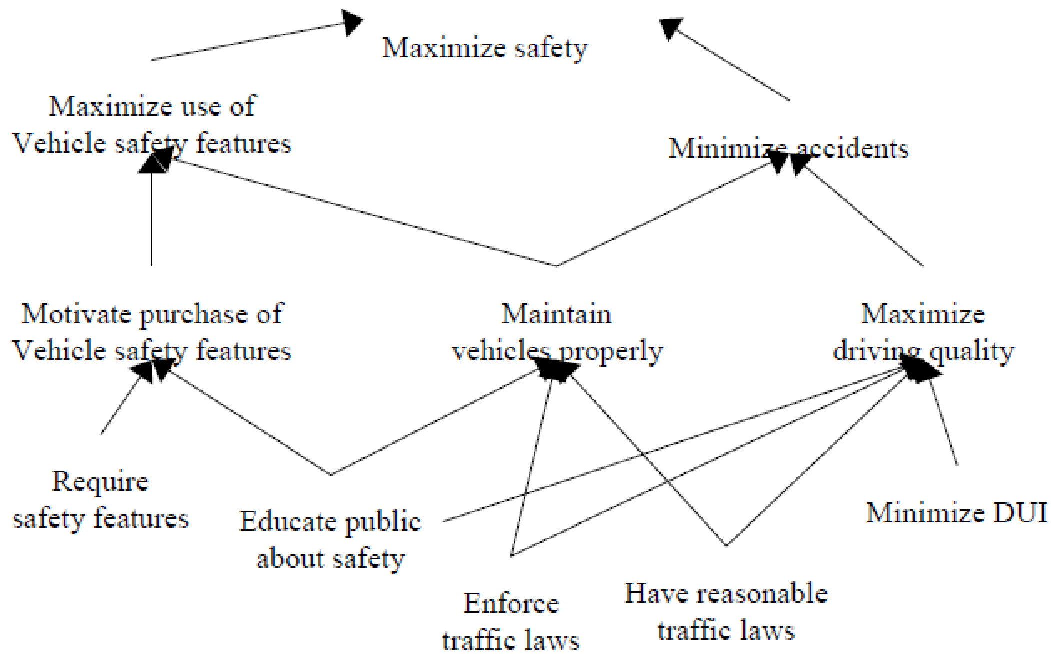


Figure 17: Means Objective Network (Clemen and Reilly, 2001)

To move from a lower level means to a higher level means objective (e.g., from the lower level means objective of Minimizing DUI's to the higher level means objective of Maximizing driving quality in Figure 17), one must determine why completion of the lower level means objective is important in view of the higher level means objective (Herrmann, 2009). More generally, each objective should be given the "why is that important" test (Clemen, 1996). The progression up the means objective chain translates to means objectives being advanced until, finally, the fundamental objective of the project or process is reached and the deliverables are realized. To move away from the fundamental objectives and towards the means objective, one must ask "how can this objective be achieved" (Clemen, 1996). For example, in Figure 17, to learn how the fundamental objective of "[maximizing] safety" can be achieved, one must look at the means objectives it is connected to; by "[maximizing]

[the] use of Vehicle safety features" and "[minimizing] accidents (Clemen and Reilly, 2001). Continually asking how to achieve the higher level means objective will generate more low level means objectives.

Fundamental objectives are constructed into hierarchies (see Figure 18). In brief, the higher level fundamental objectives are very general, while the lower level fundamental objectives are more detailed and specific because they point out important elements (or describe) the higher level fundamental objectives (Clemen, 1996). An example of a fundamental objectives hierarchy can be seen in Figure 18.

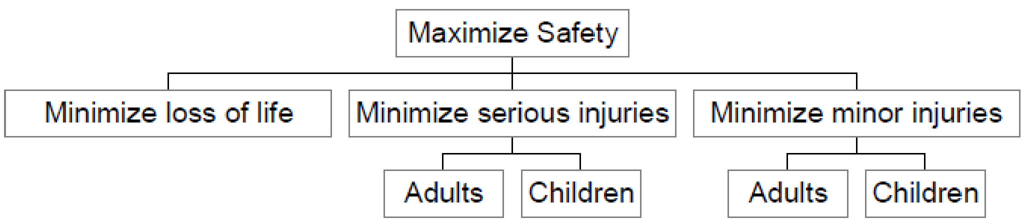


Figure 18: Fundamental Objectives Hierarchy (Clemen and Reilly, 2001)

To travel downward from the high level fundamental objective to the lower level fundamental objectives, one must ask "what do you mean by that?" So when considering the high level fundamental objective of "[maximizing] safety," asking "what is meant by that?", will lead the decision maker towards lower level fundamental objectives like "[minimizing] loss of life," "[minimizing serious injuries," and "[minimizing] minor injuries" (Clemen and Reilly, 2001). In the reverse, if one seeks to travel up the fundamental objectives hierarchy, one must ask the following question: "Of what more general objective is this an aspect?" (Clemen, 1996). So, when considering the lower level fundamental objective of "adults," one may see that this is an aspect belonging to the more general objective of "[minimizing] serious (and minor) injuries" to automobile occupants (see Figure 18) (Clemen and Reilly, 2001).

It is important to distinguish not only between low level and high level fundamental objectives, but between means objectives and fundamental objectives as well. Once the exercise of creating a fundamental objective hierarchy and a means objective network has been completed, it will be very clear which objectives are which. Furthermore, means objective networks can be connected to fundamental objective hierarchies by connecting the highest level means objectives to the appropriate low level fundamental objectives. Recall that valid means objectives will answer how to achieve the fundamental objectives that they are connected to. In the reverse, valid fundamental objectives will represent a more general aspect of the means objectives that they are connected to (Clemens, 1996). Thus, means objective chains can be connected to low-level fundamental objectives belonging to a much broader fundamental objective hierarchy. This combination creates a fundamental and means objective network. An example of one such network is presented in Figure 19 for EIP #8, Devens EIP. This fundamental and means objective network only includes Steps 1 and 2 for the sake of brevity. Figure 19 was created based on the report produced by Hollander and Lowitt (2000) for the Devens Enterprise Commission.

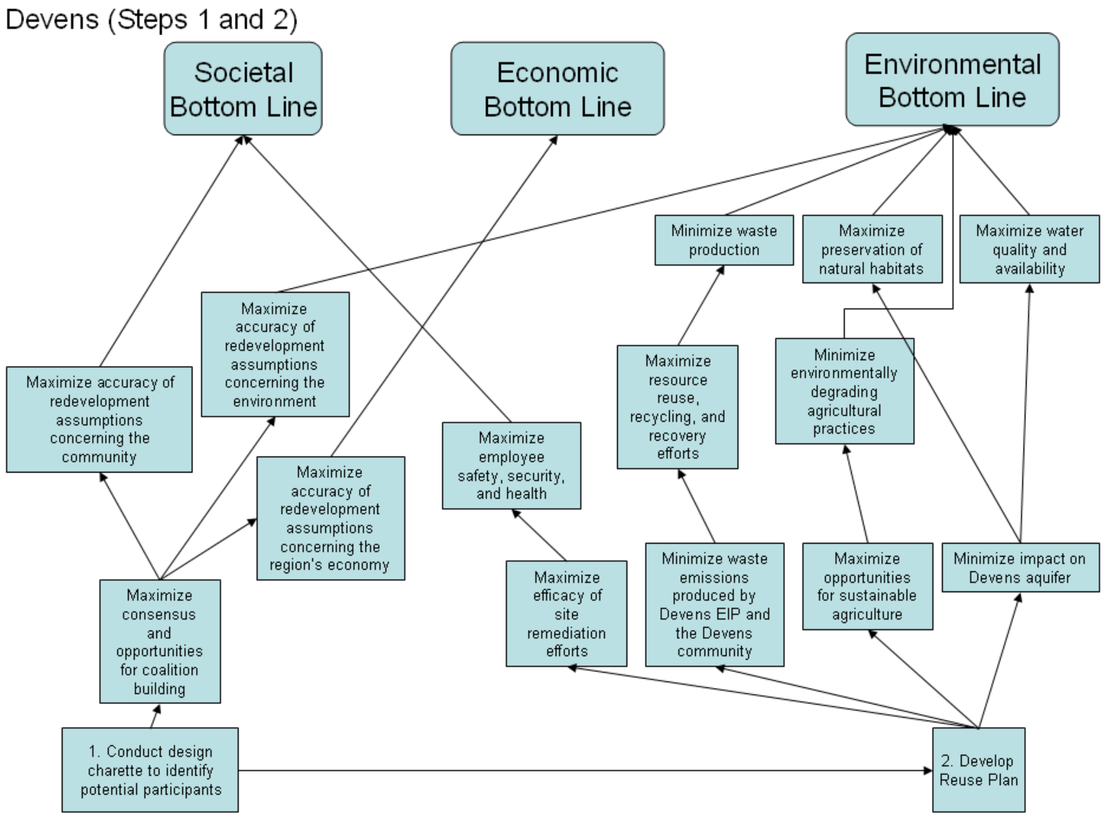


Figure 19: Part of the Means-Objective Network for EIP #8 - Devens EIP (Steps 1 and 2) (created on the basis of contributions from (Hollander and Lowitt, 2000))

In the fundamental and means-objective network for EIP #8, the means are a set of development decisions (means) that direct the development of the EIP towards the equitable triple bottom line objective. The triple bottom line is threefold to represent each benefactor (society, the environment, and the EIP inhabitants). Note that the relationship-building activity between the EIP development team and plant managers involves pre-existing plant managers because part of the site (Devens Industrial Park) already has facilities operating on it (Hollander and Lowitt, 2000). This EIP development decision process does not equally benefit all of the triple bottom line's fundamental-objectives because thirty of the means-objective chains (i.e., connection of one means objective to another until the fundamental objectives are reached) are focused on benefiting the environmental bottom line, but only ten means-objective chains are advancing the economic bottom line, and a miniscule eight means-objective chains are advancing the societal bottom line. If Devens EIP weren't already operational, then more decisions (i.e., means) would need to be incorporated into the development process to increase the efforts that will positively impact the societal and economic bottom lines. For example, decisions dealing with how the EIP will increase jobs in the community, attend to local businesses that lose customers as a result of new EIP-inhabitant competition, and ensure a decrease in the community's utility bills could be incorporated into the development decision process to ensure an increase in the societal bottom line. A summary for each of the 21 EIP development processes and the distribution of their associated means-objective chains is presented in Table 7.

Table 7: Distribution of high-level fundamental objectives that are satisfied by each of the 21 EIP development projects studied

EIP Design Process #	# of Steps Under Consid-eration	# of Times High-Level Fundamental Objective is Advanced by Means-Objective Chain		
		Environmental Bottom Line	Societal Bottom Line	Economic Bottom Line
1	11	13	6	7
2	12	27	4	23
3	6	10	7	8
4	12	15	13	11
5	20	27	18	20
6	10	13	7	12
7	10	15	11	19
8	9	30	10	8
9	12	21	8	20
10	14	31	11	25
11	4	8	6	11
12	7	16	10	17
13	6	9	10	10
14	11	23	7	15
15	6	9	9	10
16	9	18	5	8
17	8	20	13	18
18	4	13	4	8
19	6	12	8	20
20	18	27	33	18
21	9	16	17	14

This table demonstrates how many means-objective chains are centered on the environmental bottom line, the societal bottom line and the economic bottom line. As will be discussed later when the scoring of the EIP development projects is conducted, it is important to notice that a "well aligned" EIP development project will lead to a more evenly distributed development approach that contains decision-objectives that advance each of the three high-level fundamental objectives, and do not spend too much time and energy satisfying only one. More on this and the precise definition of "well aligned" will be discussed in Section 3.4.

Chapter 3: The General EIP Development Process

The development of the General Eco-Industrial Development Process (or GEIPDP) is centered around the literature on EIP development methods and the decisions and action items presented. For example, van Leeuwen et al. (2003) analyzed several different Dutch methods for developing EIPs. This paper provided a basis for how development methods can differ and gave a good background as to what EIP development processes should include. For example, the "sustainability scan" involves a survey to assess the potential for sustainable development at brownfield sites. The "sustainability scan" measures the chances for development by looking at the carrying capacity among the companies and the municipality for each option. This "sustainability scan" approach motivated the phase within the GEIPDP that deals with searching for a suitable location for the EIP. Table 8 represents a summary of the papers studied and the corresponding GEIPDP phase that they inspired.

Each paper represented in Table 8 presented me with key objectives that are associated with most EIP development projects. A large amount of background information pertaining to industrially ecological practices and implementation strategies were discussed as well. The key objectives typically received emphasis in more than one article, demonstrating their widespread appeal and importance. The phases were constructed with respect to the key objectives because these key objectives help define what actions and decisions are being made by EIP development teams and how these teams are achieving results. The popular key objectives identified from the articles in Table 8 served as goals for each phase of the GEIPDP.

Table 8: Literature about EIP Development Methods and the GEIPDP phases they inspired

EIP Development Literature	GEIPDP Phase it Inspired
"Planning Eco-Industrial Parks: an Analysis of Dutch Planning Methods" by Marcus G. van Leeuwen et al. [61]	• Phase 1 – locating sustainable area for EIP. Based on "sustainability scan" planning method • Phase 4 – identification of ideal tenants for entry into the EIP. Based on one of the three packages of the "environmental grading system" method; the second package stipulates mandatory criteria that a company must meet before entering the EIP and guides the EIP development team on how to recruit tenants
"Eco-Industrial Park Initiatives in the USA and the Netherlands: first lessons" by R.R. Heeres et al. [25]	• Phase 0A – Identifying primary actors and establishing the EIP development team. Based on description of a successful approach to EIP development that lists important actors that need to be identified early in the process • Phase 2 – identification of an anchor tenant. Based on discussion of their ability to attract other companies (seeking byproducts or vice versa) and serve as a central node in the exchange network (where almost every tenant in the EIP is exchanging byproducts or services with the anchor)
"The Application of Industrial Ecology Principles and Planning Guidelines for the Development of Eco-industrial Parks: an Australian Case Study." by Brian H. Roberts [49]	• Phase 3 – determining ideal industrial clusters. Based on discussion on clustering of facilities and businesses with respect to their industry and needed auxiliary services that can be shared
"Designing Eco-Industrial Parks: A Synthesis of Some Experiences" by Raymond P. Côté [10]	• Phase 0B – development of project scope, guidelines, and principles that will define the EIP. Based on discussion about guidelines created from multi-disciplinary research teams and multi-stakeholder groups with differing interests (implying consensus building)
"Model-Centered Approach to Early Planning and Design of an Eco-Industrial Park around an Oil Refinery" by Xiangping Zhang et al. [68]	• Phase 5 – determining the optimal layout for the EIP. Based on the last five steps of the model-centered approach which deal with modeling of members and exchanges, sensitivity analysis of key variables, improvement of structure performance (via consideration of alternative strategies, scenarios, and EIP configurations), and conclusion of design.

3.1 – Phases of the GEIPDP

The description of each phase of the GEIPDP identifies the key decisions that will be made and the constraints that restrict the actions and decisions in that phase.

3.1.1 - Phase 0A – Identifying Primary Actors and Establishing the EIP Development Team

In the first phase of the GEIPDP, the project initiator (i.e. government authority or private developer) will identify and involve primary actors who will promote industrial ecology and garner support from community groups, educational institutions, industrial associations, and relevant regulatory agencies (Gertler, 1995). This phase is numbered with a zero because it is a pre-design and development phase that includes the preliminary decisions that need to be made before beginning the EIP development project. Because most EIP development projects are initiated by government agencies working in conjunction with business associations and community organizations, this phase begins with a local government agency (e.g., a local environmental protection agency or a local economic development agency) receiving an opportunity or problem stimulus that suggests the concept of eco-industrial development. The government agency reacts to an opportunity stimulus by deciding to create an EIP development team and determining who can help this team develop a successful EIP. Before an EIP development team can be established, the government agency needs to determine what relevant community groups and business associations will be knowledgeable about and in support of industrial ecology. This decision is important because it must not leave out any members of the residential, commercial, or industrial community that could potentially support the eco-industrial development project financially, politically, or through personal involvement (e.g., becoming an anchor tenant or auxiliary service provider to the park). Inclusion of all these different members will ensure that the societal, environmental, and economic interests are being upheld throughout the EIP development project. These members will work to ensure that their respective bottom lines are maximized, leading to a beneficial triple bottom line. This is an important phase, because a good EIP development team can mean the difference between a successful EIP development project and a failing one. The government agency will typically administer a survey, hold recruitment conferences, and advertise at community meetings in order to determine members of the EIP development team (representative of community groups, the regulatory agency, and industrial associations) and potential tenants as well (Koenig, 2005).

Constraints that the newly formed EIP development team (and its associate government agency) must work to overcome are present. The first constraint is the accessibility of actors of interest. The EIP development team must determine how to find the actors (e.g., investors, industrial ecology consulting team, potential tenants, etc.) that will not only promote the eco-industrial development, but will play an active role in its design, development, and operation.

The second constraint is a lack of inter-firm communication and trust. A trusting relationship can develop through unforced communication between members of organizations that desire to participate in the EIP development project. Commitment to the EIP development project will come from organizations that believe fellow participants share the same economic, environmental, and societal goals as them. Primary actors that communicate freely and trust one another will increase the likelihood of building strong symbiotic linkages.

3.1.2 - Phase 0B – Gaining Consensus and Establishing Goals, Scope, and Implementation Strategy

Once the EIP development team is established, the team can begin to work in conjunction with the project initiating government agency to start building support for the EIP development project within the residential, business, and industrial communities. Phase 0B is concerned with establishing the goals, scope and implementation strategy for the EIP development project. Phase 0B also includes a zero in its name because it is more of a series of actions that lead to the determination of goals and objectives that will build the foundation of the EIP development project, as opposed to a series of decisions and evaluations and creation of old and new goals and objectives that must be made before the next phase can begin. Phase 0B begins with the EIP development team educating the members of the surrounding community, business associations, and members of management from the region's leading industrial companies about the principles of industrial ecology and what they intend to accomplish through the EIP development project. Upon receiving feedback and suggestions from stakeholders, the decision-makers (i.e., the EIP development team) must construct a proposal that defines the goals and scope of the intended project and estimates the expected economic, environmental, and societal impact that the EIP will have on the given region. This proposal should include ideas and concepts that received substantial support from the primary actors and stakeholders during earlier consensus building events, a preliminary analysis exploring what areas and industries may be suitable for such a project, and important guidelines and principles that potential tenants and EIP business partners should be cognizant of. The proposal would be drafted by the EIP development team with funding from their associate government agency and primary actors who want to take an early lead. The target audience for the proposal is potential investors, new government agencies, and potential tenants that could each provide funding and support for the EIP development project. The solution to this phase would be a set of requirements, goals, limitations, an implementation strategy that strengthens consensus between stakeholders and decision-makers, and a proposal for investors and potential tenants.

Constraints that limit Phase 0B include differing opinions between decision-makers and stakeholders, availability and accuracy of information for preliminary analysis. Differing opinions may include the "not in my backyard" viewpoint from community groups. It is up to the EIP development team to incorporate guidelines that reduce the presence of the EIP (e.g., reduce industrial noise levels, reduce heat or waste pollution coming from tenants, etc.) through regulatory actions and ecological design methods. The availability of information can serve as a constraint because the EIP development team cannot draft a proposal that details operations at the park and the associated benefits from participating in the project. Careful assumptions must be made with respect to the agreed upon principles and guidelines of the EIP.

3.1.3 - Phase 1 – Locating a Suitable Site for EIP

In Phase 1 of the GEIPDP, the EIP development team will locate a sustainable area, within a given nation, for EIP development. The EIP development team will:

decide what its criteria for a suitable site will be; determine their alternatives (e.g., compare available brownfield site facilities with potential greenfield development sites); and gather information about the nation's industrial activity, labor market and resource pools. This phase is important because it allows the EIP development team to conduct the search routine using a high-level perspective to determine whether the local industries can create symbiotic linkages (for a prolonged period of time). At this point, the EIP development team would consider developing a medium for companies and community members to freely view each other's byproducts and begin communicating ideas as to how these byproducts can be reused. In addition to symbiotic linkage considerations, this team must consider whether the country can support industrial activity (and if so, what type), or whether the regions within the country have a population that is willing and able (i.e., multi-disciplinary population of trained professionals seeking employment) to work in the facilities located within the EIP. It is safe to assume that the EIP will include some heavy industrial activity. With this in mind, it is necessary to search for industrially zoned land that is not too close to residentially or commercially zoned land. This phase should motivate the EIP development team to conduct a feasibility study of the country in question to help organize the different issues and considerations linked to the EIP project (especially those of regulatory issues). The feasibility study could be used as a tool to attract additional investor funding, potential tenants, and additional government grants.

Constraints to the site location search will help determine which alternatives should be excluded from future consideration. The resource availability and proximity constraint would exclude sites that are not close to sources of water, energy (or an energy generation plant), or large scale resources that tenants within the EIP may require on a frequent basis. To minimize the environmental impact of transporting resources, a site that is located near the country's resource rich regions would be ideal; sites that are relatively isolated and difficult to reach by road, rail, or airport would be excluded.

Secondly, the existing economic structure of the country where the EIP would be situated in would be used as a constraint. Most EIP development projects are aimed at reigniting industrial and economic activity in regions of countries where the economy is suffering. For example, Cape Charles was once a thriving, economically sound town located in Virginia's historic Eastern Shore. As part of a broad economic revitalization effort, the Northampton County Board of Supervisors and the Cape Charles Town Council signed a joint memorandum to create the Port of Cape Charles Sustainable Technologies Industrial Park. As of 2004, the EIP has produced 395 direct jobs, and is projected to produce more in the future (Heeres et al., 2004).

The third constraint is the environment's capacity for absorbing industrial activity. Each of the alternative sites needs to be evaluated to determine how great an impact the EIP's daily operations will have on the surrounding habitat (e.g., bodies of water, plant vegetation, etc.), pre-existing communities of animals, and atmosphere in the nation. The regulatory agency can play a role by providing policies and regulations that can help define this constraint in detail.

The fourth constraint pertains to the ability to raise community support. Opposition from the surrounding community can delay the EIP project or even cause it to fail, while support from the community can help it flourish. A community that cannot be persuaded to participate in development efforts should serve as an exit flag for EIP development teams. Existing industrial activity in the country can serve as a constraint to the number of options for industrial clusters as well. Without a strong mix of industries with similar resource needs and diverse byproduct streams within the country, it may be difficult to convince new potential tenants to enter the EIP. Trade between the EIP and the surrounding community can be constrained if the EIP does not produce products or services that the community is in demand for. If a site is not located in a business and industry friendly country, then the EIP development team must use this measure as a constraint for site selection.

3.1.4 - Phase 2 – Identifying an Anchor Tenant

Once a suitable site has been selected by the EIP development team, it is time to begin considering the makeup of the EIP tenants. Phase Two of the GEIPDP is a search routine that identifies an ideal anchor tenant for the EIP. As mentioned previously, an anchor tenant is the central figure within the EIP who engages in the most byproduct exchange opportunities (between tenants and the external community) and attracts intermediate companies to the EIP who can turn byproducts into useful resources for other tenants (Lowe et al., 1997). The EIP development team must decide what required properties the anchor tenant must have in order to take full advantage of the site's surrounding industry profile, available workforce, and room for sustainable growth.

Constraints to finding a suitable anchor tenant include raising interest level among potential tenants, local environmental regulations and zoning permissions.

Gaining the attention of potential anchor tenants and giving them a reason to join the EIP can serve as a constraint because the company in question may not want to partake in the considerable amount of initial investment required (in the form of funding and time diverted from usual operations to join the EIP). An anchor tenant must truly believe in the concept of industrial ecology (and its benefits) and be willing to assume the risks associated with this long term investment. The EIP development team needs to search for industrial leaders who are open to change and have a green production initiative already in place (e.g., employing an Environmental Management System in alignment with the ISO14000 series).

The next constraint to finding an EIP anchor tenant is the local environmental regulations. Potential anchor tenants will be considered if their operation's effluents are at levels in accordance with regional law. Further consideration as to how this anchor tenant disposes of its effluents (e.g., public waste management and landfill system, hazardous waste storage, or byproduct exchange), will also factor in. The EIP development team needs to assess regional environmental policies and zoning covenants to determine what types of industries would have a hard time conducting business freely. If regional regulations prohibit use of a needed resource in a certain manner, require disposal of wastes using expensive procedures, or do not allow particular industrial practices within the zone the site is on, then exclusion of a series of potential anchor tenants will ensue.

3.1.5 - Phase 3 – Identifying Compatible Industrial Clusters

The third phase of the GEIPDP deals with identifying ideal cluster linkages that the EIP should be focused around. This decision is dependent upon the phases preceding it because the site selected will already have a set of industries and businesses surrounding it. Based on the location selection phase, and the anchor selection phase, the choices of suitable, compatible industrial clusters that will define the EIP can be determined. Each industrial cluster is one or more firms in the same industry, who are situated nearby one another within the EIP (e.g., cement manufacturing companies) because they share similar needs with respect to utilities and auxiliary service. Moreover, the EIP will include multiple industrial clusters with each of these clusters' locations being determined with respect to maximizing beneficial symbiotic relationships between complementary industries (i.e., byproduct, waste energy, or waste water exchange project). The EIP development team must determine what industrial clusters, upon collocation, can maximize the number of byproduct, energy, and water exchanges, create the most jobs relevant to the surrounding workforce, and minimize waste created by the EIP. These industrial clusters should be compatible with business and industrial communities outside of the EIP in order for symbiotic linkages to be easily identifiable. EIP development teams need to conduct mass, energy, and water balance evaluations to ensure that the proposed symbiotic linkages can indeed exist without any one member of the network being put at risk from being led to rely on a temporally depleting byproduct source. Table 40 (in the appendix) depicts a short list of different industries, their typical inputs and outputs, and how these byproducts may be applicable to other industrial clusters. For example, the cement industry utilizes calcium, silicon, aluminum and iron to produce cement. Some byproducts from other industries may included (but are not limited to) fly ash, foundry sand, baghouse dust, refractories, causticizing residue, tire scrap, and mine tailings. The table goes on to present how the cement industry produces cement kiln dust as a byproduct. One example of how cement kiln dust can be reused is with respect to the agricultural industry; as a soil amendment, waste solidification agent, or general soil stabilizer. Figure 5 presents the different symbiotic linkages that could potentially arise if a combined heating and power plant were to serve as anchor for an EIP. An EIP development team can use comprehensive industrial databases and modeling tools of this nature to develop a conceptual EIP that would highlight many different potential byproduct exchanges based on common industry practices. However, using these databases is limited because each individual company within these industries can employ vastly different operation processes that lead to a wide range of energy, water, and material requirements. Since a mass, energy, and water balance need to be conducted to validate the network of symbiotic linkages within the park, EIP development teams should exercise caution in making industry generalizations with respect to these variables.

The constraints to determining ideal industrial clusters for the EIP are as follows: regulations deterring byproduct suitability for reuse, changes in consumption rate of region's resource pools, and community acceptance of candidate industrial clusters. Regulations like the Resource Conservation and Recovery Act (RCRA) can deter byproduct exchange by limiting the types of byproducts deemed suitable for reuse. This constraint will exclude the industrial clusters that typically produce hazardous outputs because these hazardous byproducts must adhere to the disposal or storage procedures outlined in the RCRA and may not permit reuse of any kind by any entity. It is important for the EIP development team to be cognizant of regulations and policies that will make it difficult for certain industrial clusters to contribute to the byproduct exchange network.

The second constraint that must be considered deals with how the potential industrial clusters will change the rate of consumption of the region's resources once in the EIP. If the wrong industrial cluster is participating in the EIP and consuming resources shared by neighboring communities and businesses, then it will only be a matter of years before these resources are no longer as plentiful and the cost of these resources increases. Screening industrial clusters in terms of their resource consumption potentials will help to ensure economic and environmental viability for the future. To determine whether an industrial cluster will drain the region's resource pool, an industrial ecology analysis needs to be conducted and the metabolism of the currently existing communities, businesses, and other entities must be considered in conjunction with the candidate industrial clusters'. This constraint will serve to eliminate industrial clusters whose producers may want to move from the EIP if resource costs become too high.

The last constraint to the industrial cluster search phase involves dealing with community acceptance of the proposed industrial clusters. The community may oppose the entry of a given industry because they feel it may hurt the surrounding smaller to medium sized businesses, provide jobs that they feel overqualified for, or because the industry has a history of negatively impacting the surrounding environment in other areas where it operates. It is up to the EIP development team to recover feelings and opinions from community groups about what industrial clusters would fit more than just the EIP, but the entire region in general. Industrial clusters that do not "agree" with the existing community's inhabitants will probably face problems getting permits and may even have trouble finding qualified employees for its tenants' facilities.

3.1.6 - Phase 4 – Identifying Tenant Organizations

Once a given number of industrial clusters have been selected to characterize the EIP, the next phase focuses on deciding what companies to fill these industrial clusters with. The EIP development team needs to determine which businesses, upon entering the EIP, can maximize economic benefit to (1) themselves, (2) neighboring tenants, and (3) the surrounding community. Typically, organizations with eco-friendly practices and a history of overcoming internal and external change will attract the attention of EIP development teams. Resilient organizations are desirable tenants because they can invent new ways to utilize previously deemed useless byproducts and are flexible enough to adapt to changes within the EIP.

. Additionally, the ideal tenant would be a medium to large size company (with ample reserved capital) that is not afraid of the large initial investment required before operations can even begin. To search for potential tenants, the EIP development team would continue to hold region wide design charrettes. Design charrettes are events that bring together relevant leaders of industrial association, business leaders, and community leaders in an attempt to shed light on the fundamental challenges associated with developing an EIP in their particular region and to discuss how these challenges may be overcome. Design charrettes also allow EIP development teams to gain information about different businesses (e.g., their annual energy, water, and material flows, their history with environmental management systems, and other pertinent information). In addition, the EIP development team may want to set up a website highlighting the features of the EIP and discussing what types of tenants it's they're interested in recruiting. It is important to consider as many alternative companies as possible, because the wrong company could interfere with the potential for additional byproduct exchanges on account of lack of creativity or conservative practices.

Phase Four also has a set of constraints that deal with the availability of proprietary information and byproduct production rates of each organization. The EIP development team is responsible for managing the information that is provided to them by potential tenants. If the potential tenant fears for the safety of their proprietary information, then they may not even apply for a vacancy, thereby limiting the total number of applicants and making it harder to establish byproduct exchanges. The EIP development team must instill trust between themselves and the potential tenants; as well as between the potential tenants that are applying alongside their industry competition. This can be done by taking a black box approach; allowing potential tenants to search for potential byproduct exchange partners anonymously. Potential tenants would only be able to see what other companies require as inputs and produce as outputs (along with the associated requirements for their inputs and data pertaining to byproduct quality and amount). This constraint can be managed by the EIP development team and the collaborative approach can be demonstrated as beneficial for involved tenants; however, trust building between competing businesses will not always work and highly independent potential tenants will not wish to participate.

The second constraint factoring into this phase's decision process is the consideration of byproduct production rates of each organization. This is important, because most companies do not manufacture the same amount of a given product year round; meaning the byproduct production rate will fluctuate with respect to market demands. If a company is able to produce an annual amount of a given byproduct, and another tenant is interested in reusing it, the tenants need to plan a byproduct exchange that will agree with demand and supply of that byproduct regardless of the time of year. This constraint must be taken into consideration by both tenants, because they may find themselves disposing of excess byproduct or having to contact suppliers for additional resources at a higher cost (thus, reducing the economic advantage of engaging in the bilateral agreement). The EIP development team should ensure that byproduct exchanges will be beneficial for both parties and that a contingency resource supplier is available for its potential tenants.

3.1.7 - Phase 5 – Determining Optimal Layout

The final phase of the GEIPDP is to determine the optimal layout of the EIP. This involves creating several prototype scenarios that allow the EIP development team to explore how different arrangements of the anchor tenant, industrially clustered tenants, and auxiliary services can maximize economic and sociological benefits while minimizing environmental impacts. The EIP development team must consider the effluents from each industrial cluster and decide which industrial clusters need to be situated next to each other. Care must be taken to ensure that historically incompatible industries (e.g. food processing industrial cluster neighboring a hazardous chemicals industry) are not in close proximity; if ignored, the health and safety of the surrounding community could be at stake. In addition, the EIP development team must consider landscape design strategies (e.g., buffer zones) that will mitigate industrial noise, air pollution, and prevent degradation of wildlife and native plant species in the area (Cohen-Rosenthal and Musnikow, 2003). Furthermore, the EIP development team should consider public accessibility to and from the EIP; ensuring that there is proper signage in the appropriate places, that nearby roads are well connected to airports, seaports, and/or train stations (for efficient transportation of incoming and outgoing goods), and that the roads connecting to the EIP are accompanied with sidewalks (i.e., for employees that like to walk or bike to work). Overall, the EIP development team needs to work closely with management in each tenant organization to ensure that each party is satisfied with its neighbor and that planned and new byproduct exchanges can be implemented successfully.

Constraints associated with the EIP layout optimization phase include facility footprints, firm-by-firm operational requirements, shared infrastructure proximity, and incorporating room for tenant expansion. Shared infrastructure proximity is a term used to describe the location of infrastructure and services like public transportation, roads, phone and internet lines, waste-water collection facilities, etc. that are strategically placed nearby the industrial clusters and organizations that need them the most in order to minimize the cost of utilizing and providing these shared infrastructures and services. With the potential for each tenant to occupy more than one facility, and with different accommodations and amenities being required, the EIP development team must determine how to arrange the tenants in such a way that common services and infrastructure can be shared without compromising any of the tenant's business operations. The different combinations of tenant facility footprints will serve as a constraint limiting where the industrial clusters will be situated and how the tenants can be arranged within the EIP (Lowe, 2001).

The second constraint deals with each tenant's operational requirements. For example, certain tenants may require immediate access to the road for emergency personnel access, higher frequency of incoming and outgoing truckloads, or other transportation related requirements. If this is the case, then the tenants in question would be constrained to locations closest to the roads within the EIP. If another tenant executes operations that produce a large amount of noise, then the EIP development team must situate them farther from the boundaries of the EIP to preserve the noise level of the EIP surroundings (Lowe, 2001).

The third constraint deals with the proximity of tenants who must access shared infrastructure. The EIP development team needs to categorize each tenant by what infrastructure they intend to employ to ensure that the infrastructure is relatively accessible to each tenant. It is important to note that as the tenant's facility becomes more and more remote from the infrastructure it needs, its operational costs will increase. Shared infrastructure is dependent upon byproduct exchanges and industrial clusters, so this constraint may be easier to factor in on a cluster by cluster basis (Lowe, 2001).

The final constraint may be the most limiting one: ensuring tenants have room to expand. The EIP development team needs to work closely with each tenant's management team to determine the potential forms of expansion (e.g., additional production plant, warehouse, increased energy usage, etc.), the probability of expansion, and whether such a change will occur in the short term, or in the long term. Depending on feedback from each tenant, the EIP development team can decide how much land to set aside, and how possible it will be to situate the reserved land near the tenant's current location (or at least within the same industrial cluster). This is difficult because a great number of uncertainties have to be taken into account in addition to other considerations already in play. After several layouts have been conceptualized, the excess space within the EIP must be managed to allow for new businesses and expansion of current tenants; this constraint places a limit on how much the EIP can grow (in the long term) without purchasing and zoning new land.

A summary of the decisions being made during each phase and their associated constraints is shown in Table 9.

Table 9: Decisions Made during each Phase of the GEIPDP and their associated constraints.

Phase #	Phase in EIP Development Process	Constraints
0A	Identify, involve, and establish primary actors internally (EIP development team) and externally within local business, regulartory agencies, and community	Actors of interst may not be accessible or easily identifiable; inter-firm communication and/or trust may be hampered for whatever reason; actor in decision making power may change;
0B	Establish goals, scope, and implementation strategy of ideal EIP between ALL stakeholders/decion makers	Differing opinions of what's most important, information availibility, "not in my backyard" community member views
1	Locate Sustainable Area for EIP - Industrial Zone Search and Initial Feasibility Analysis of Region with respect to its Inhabitants and Resources	Resource (energy and water included) proximity and supply, existing economic structure and policy, environmental regulations (on hazardous waste, noise, etc.), available technology and infrastructure, environment's absorption capacity, and workforce availibility, existing nearby industrial activity, community support, cleanup liability (brownfield redevelopments)
2	Identify ideal anchor company/tenant	Raising interest level of favored potential anchor company, resource availability (surrounding ecosystem), community support, Local Environmental regulations, zoning permissions
3	Identify ideal industrial-cluster linkages with respect to chosen location (also consider required supporting non-industrial inhabitants) and projected anchor/s	Local Environmental regulations, byproduct suitability for reuse, community acceptance, ecological analysis (high in virgin materials), existing industry's feedstock pool for current economy and community, zoning permissions,
4	Identify and Secure inhabitant businesses for each industrial (and non-industrial support service) cluster	Availibility of proprietary information, byproduct production consistency as well as amount, relationship with local producers/businesses
5	Determine Optimal Layout - EIP Prototype Scenario Exploration	Involved facilities' footprints, firm-by-firm operational requirements (watch for conflicts), Shared infrastructure proximity (minimize transportation of resources between industrial clusters and service facilities), trust among tenants, health and human services and facilities, room for expansion for each tenant,

3.1.8 - Determining Need for Revisions to GEIPDP

To determine its completeness and validity, the GEIPDP was compared to the steps employed by the 21 EIP development processes. EIP #17 (Cape Charles Sustainable Technology Park) is one such example of the 21 EIP development processes studied and can be seen in Table 10. EIP #17's development process was compared, along with the other 20 EIP development processes, to the GEIPDP. An example of the comparison can be seen in Table 11.

Table 10: EIP #17 - Cape Charles Sustainable Technology Park's Decision Process (Kim, 2009)

Phase/Step Exercised	Activities in this Phase/Step
1. Development Background	Explore ways to invest while protecting natural assets (maximize both economy and environment) by developing in a manner that would benefit business, the environment and the county's people
2. Sustainable Development Action Strategy	2.1 Plan and hold community workshops, task forces, meetings and events to educate the public and centralize decision-makers and stakeholders
	2.2 Determine which industry sectors to target; Northampton chose agriculture, seafood and aquaculture, heritage tourism, research and education, arts and crafts, local product, and sustainable technologies (list of 3000 companies as prospects)
	2.3 Identify vital natural, historic and community assets that would need to be preserved and capitalized on to successfully develop and sustain the EIP
3. Organize Planning Team	3.1 Include professional members like designers, architects, and engineers; federal, state and local government regulatory and support agencies; public and private potential investors; potential corporate tenants.
	3.2. Build a diversified economic base by attracting and incubating new companies while retaining and expanding existing companies (or local potential tenants)
4. Master Plan	Develop guidelines (bylaws perhaps?) that integrate the park w/ the historic town and natural landscape - redevelopment of roads, utilities, sewers, water

	management (reuse and recovery system), wetland treatment for water recycling (half the site = ecological infrastructure), created wetlands, woodlands, and shrub wildlife habitat, design of natural systems (e.g. passive lighting and ventilation), and renewable power generation (wind and/or solar)
5. Sustainable Technology Incubator	Develop a multi-tenant manufacturing and office building that utilizes renewable energy (and cuts down on energy, resource, and operational costs) in order to invite tenant companies to move in without having to construct ALL their own facilities

Table 11: Comparison of GEIPDP to EIP #17 - Cape Charles Sustainable Technology Park's Decision Process

GEIPDP Phase	Corresponding Phase/Step
0A	2.1
	begin 2.2
	3.1
0B	1
	4
1	2.3
2	None related
3	finalize 2.2
4	3.2
5	5

In this example, all but one phase within the GEIPDP corresponds to a planning step executed during the development of Cape Charles Sustainable Technology Park. Note that some of the planning steps used at Cape Charles correspond to more than one phase in the GEIPDP. This occurs because some planning steps must be revisited later on during the process and are finalized only after other decisions have contributed to new information and, thus, enable the earlier planning step's decision process to be conducted better. These occurrences would represent a nested loop within the general decision process (recall Figure 16 from Mintzberg et al., 1976) because they require the decision-maker to repeat a past routine. The fact that all of the planning steps used at Cape Charles match at least one item in the GEIPDP demonstrates a good match. For example, the "Organize Planning Team" and creating of a "Master Plan" steps in Table 10 (Steps 3 and 4 respectively) match closely with the preliminary phases described by the GEIPDP's phase 0A and 0B. However, this serves as only one example of a development process comparison between the GEIPDP and the 21 EIP development processes studied. A full presentation of how the GEIPDP corresponds to the 21 EIP development processes is provided in Table 12.

Table 12: Correlation between GEIPDP and the 21 EIP development processes studied

EIP Design Process #	Does the GEIPDP Phase have Corresponding Steps in this EIP Design Process?						
	0A	0B	1	2	3	4	5
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	No	No	No	No
4	Yes	Yes	Yes	No	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	Yes	Yes	No	No	Yes	Yes	No
7	Yes	Yes	Yes	Yes	Yes	Yes	No
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	No	Yes	Yes	No	Yes	No	Yes
10	Yes	Yes	Yes	No	Yes	Yes	Yes
11	Yes	Yes	Yes	N/A, EIN	N/A, EIN	N/A, EIN	N/A, EIN
12	Yes	Yes	Yes	No	Yes	Yes	Yes
13	Yes	Yes	Yes	No	Yes	Yes	Yes
14	Yes	Yes	No	Yes	Yes	Yes	Yes
15	Yes	Yes	Yes	No	Yes	Yes	No
16	Yes	Yes	Yes	No	No	Yes	Yes
17	Yes	Yes	Yes	No	Yes	Yes	Yes
18	Yes	Yes	No	No	Yes	No	No
19	Yes	Yes	No	Yes	No	Yes	No
20	Yes	Yes	Yes	No	No	Yes	Yes
21	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Totals (Yes: 113, No: 30)							
Yes:	20	21	17	8	16	17	14
No:	1	0	4	12	4	3	6

Please note that EIP design process #11 is for an eco-industrial network (EIN). As mentioned earlier, EINs don't require a common physical location for the participants. Since phases two through five pertain to identifying ideal inhabitants for the EIP and optimizing its layout, they do not directly apply to EINs. Instead, EINs are typically involved with providing a medium for different regional industrial leaders to advertise their byproducts and allowing these same industrial leaders to "shop" for other potentially useful byproducts created by other businesses, organizations, and other communities in the region. These later phases will be deemed non-applicable when dealing with EINs later as well (i.e., in Table 14). These results demonstrate that a total of 30 steps from every EIP development process studied did not find a corresponding phase in the GEIPDP, while 113 steps did match. This corresponds to a 79% match rate, meaning that there is room for improvement of the GEIPDP. For this reason, a revision to the GEIPDP was considered necessary. The name of this new, more inclusive development process is called the Revised EIP Development Process (or REIPDP).

3.2 – Development of Revised General EIP Development Process

The revisions to the GEIPDP yielded the REIPDP. These revisions were made by considering which steps within the 21 studied EIP decision processes were not being emphasized in the GEIPDP enough (or, in some cases, at all). Phase 1 in the GEIPDP appeared too early in the process and, within the 21 EIP projects studied, was found to rely on preceding decision phases before it could initiate. Several of the finalizing decisions within the 21 studied EIP decision processes (e.g., implementation, construction, and management board organization) were also found to be neglected often by the GEIPDP, so phases reflecting them are also included in the REIPDP. To verify that the REIPDP more accurately portrays the 21 EIP decision processes studied, a matching between the phases of the REIPDP and the steps in each EIP decision process was made and is shown at the end of this chapter in Section 3.3. A comparison between the GEIPDP and the REIPDP can be seen in Table 13. It is important to notice that Phase 0A and 0B are provided with a little more detail in their description. The green phases in the REIPDP of Table 13Table 13 show which phases were newly added or modified significantly.

Table 13: Comparison between Phases in GEIPDP (on left) and the REIPDP (on right)

Phase #	Phase in GEIPDP	Phase #	Phase in REIPDP
0A	Identify, involve, and establish primary actors internally (EIP development team) and externally within local business, regulartory agencies, and community	0A	Identify, involve, and establish primary actors internally (EIP development team) and externally (within local business (resource exchange network, industrial associations, etc.), regulatory agencies, and community) via regionwide social function (conference, meeting, symposium, etc.)
0B	Establish goals, scope, and implementation strategy of ideal EIP between ALL stakeholders/decion makers	0B	Establish goal, scope, implementation strategy, principles, guidelines for potential tenants and proposal for development of region's "ideal" EIP. ALL stakeholders and decision makers should be in consensus by the end of this phase (Also called Terms of Reference)
1	Locate Sustainable Area for EIP - Industrial Zone Search and Initial Feasibility Analysis of Region with respect to its Inhabitants and Resources	1	Develop Action Plan
2	Identify ideal anchor company/tenant	2	Brownfield/Greenfield site search and evaluation (More Detailed Feasibility Analysis of Region with respect to its Inhabitants and Resources). Followed up with Acquisition, and Preparation (includes site remediation, infrastructure and public services installation, and public facility construction) after authorization
3	Identify ideal industrial-cluster linkages with respect to chosen location (also consider required supporting non-industrial inhabitants) and projected anchor/s	3	Identify ideal industrial-cluster linkages with respect to chosen location (also consider required supporting non-industrial inhabitants) and projected anchor(s).
4	Identify and Secure inhabitant businesses for each industrial (and non-industrial support service) cluster	4	Identify, Evaluate and Secure inhabitant businesses for each industrial (and non-industrial support service) cluster
5	Determine Optimal Layout - EIP Prototype Scenario Exploration	5	Determine Optimal Layout - EIP Prototype Scenario Exploration
		6	Organize and Determine regulatory and managerial responsibilities to be held by EIP management and regulatory agents
		Omega	Implementation and Construction

3.2.1 - Modification of Original Phase 1 (now REIPDP Phase 2)

Originally, Phase 1 gave the EIP development team the responsibility of searching the entire nation in question for suitable EIP development sites. As opposed to searching the entire country for ideal EIP development sites and conducting feasibility studies to differentiate between a large number of alternative sites, most EIP development teams are directed (by private developers or government agencies) toward a small set of industrially zoned land options within a given region (e.g., within a local government's jurisdiction). Within this region-based search, decisions focused on which site to acquire and how economically feasible it would be to prepare for EIP development (i.e., how much site remediation would be required and how difficult will it be to acquire land before project implementation can begin). EIP development teams still reported having to conduct regional feasibility analyses investigating the byproduct exchange potential of each region, but they did not have to worry about whether the proposed site alternatives would be capable of gaining industrial zoning permits (unless the site in question was not yet designated as a greenfield site). In addition, this action item can be conducted in more detail during this phase because the solution space (i.e., all available industrially zoned sites within the region(s) under consideration) is reduced from searching for nationwide cities and towns with an industrial presence and large material, energy, and water flows, to searching for brownfield and greenfield sites that have already been nominated by funding sources or other primary actors (and are typically neighboring other industrial scale organizations) (Casavant, 2006).

The narrowing of the scope of the site search allows the EIP development team to spend more time focusing on factors like the degree of need for site remediation (i.e., the level of contamination existing at each proposed brownfield site) and challenges associated with the site acquisition process. In addition, less time will be spent determining whether the surrounding community will oppose a new industrial presence. For example, if the site under consideration is already an industrially zoned brownfield site, then it may be safe to assume that the nearby community would appreciate a cleaner, less noticeable and more socially beneficial system at that site. The REIPDP moves Phase 1 of the GEIPDP to Phase 2 (to be discussed later) to account for the EIP development team's guided regional site search and to include the additional decisions often associated with this search.

3.2.2 - Omission of Original Phase 2

The phase involving a search for an ideal anchor tenant has been omitted from the REIPDP because a large number of the EIP development processes studied did not include a step outlining this search. In theory, this search would be valuable to the EIP development team in helping narrow down ideal industrial clusters for the EIP. However, a phase that does not correlate with 13 out of the 21 EIP development processes studied does not belong in a general EIP development process. Because so few a number of EIP development teams reported a search for an anchor tenant, it is unreasonable to incorporate this search into the GEIPDP's Phase 4 (the search for tenants to recruit into the EIP). In support of this omission, it is important to recall that anchor tenants are not necessary and that, in some cases, no EIP tenant wants the responsibility of being the anchor because it can lead to a complex interdependence on other tenants within the EIP and vice versa. This interdependence can lead to inflexibility in operations on the part of anchor tenants who want to keep symbiotic relationships intact by trying not to vary their output, but at the risk of being incapable of handling seasonal demand variations.

3.2.3 - Revised Phase 1 – Developing Action Plan

A revision to the phase occurring after Phase 0A and 0B was created to encompass the earlier decisions more commonly reported by the 21 EIP development processes studied. After Phase 0B is complete, the development process switches to the Revised Phase One. This phase deals with decisions pertaining to development of the action plan. The EIP development team must use the agreed upon guidelines, principles, and information from the proposal (developed during Phase 0A and 0B) to develop an action plan for the EIP project. This action plan must acknowledge challenges to development, expected benefits applicable to decision-makers and stakeholders (e.g., a respectable ROI, regional economic revitalization, job creation, environmental waste reduction, and other benefits), expected sources of funding (based on feedback from funding sources with respect to the proposal), and roles and responsibilities of decision-makers during the coming phases of the EIP project (Koenig, 2005).

Constraints to the Revised Phase One focus on uncertainties surrounding the prospective tenants and resource and utility cost fluctuations in the future. Since this phase appears early in the development process, characteristic information (describing operational specifications, production processes and facility layouts) about the probable tenants is still not available. Survey results received from potential tenants may aid in making assumptions, but without a clear industry makeup of the EIP, it will be quite challenging for the EIP development team to accurately discuss associated benefits with the project. As with the proposal, the EIP development team must rely on the EIP guidelines, assumptions, and available information when making assumptions to estimate benefits within the action plan. The second constraint governing this phase focuses on resource and utility cost fluctuations in the future. These costs can be estimated with relatively good accuracy, but it will be difficult to account for how heavily unknown tenants will utilize these resources and utilities. This constraint will limit the development of an action plan because it will add to inaccuracies in the financial viability assessment of the EIP project and influence how the EIP development team approaches role and responsibility assignments for decision-makers and primary actors.

3.2.4 - Revised Phase 2 – Conducting the Site Search, Acquisition, and Preparation

During the Revised Phase Two, the EIP development team searches for a suitable site for the EIP project. This search routine is closely followed by acquisition and site preparation. As discussed earlier, the EIP development team will be presented with a list of industrially zoned land that the local government has identified as economically disadvantaged in need of revitalization. The government agencies typically target sites that have been abandoned by previous owners on account of site degradation (e.g., hazardous material exposure, failing infrastructure, brownfield sites, or aging facilities) or because the company moved its operations elsewhere. This is a preferred option because it does not require brand new construction (at a high cost) for new facilities, new zoning permits, or further reduction of natural undisturbed land. In addition, the act of employing a previously used site (versus a new site) can be considered a large scale recycling project because a currently existing set of facilities is being restored and reused. When considering sites, the EIP development team must use the degree of needed site remediation that will be required as a criterion for choosing an EIP site. After a site has been selected, the acquisition procedure will begin. This procedure may be repeated later during the REIPDP in order to increase the size of the site and allow for new tenants and tenant expansion. The EIP development team then moves on the site preparation segment of this phase. This action item requires funding from sources targeted by the proposal and is sometimes subsidized by government agencies to attract potential tenants. Once the necessary funding is secured, the EIP development team will hire site clean up specialists, construction management companies, and utilities companies. These personnel will begin conducting site remediation efforts, installing baseline infrastructure and public services, building common facilities, and conducting other tasks that will prepare the EIP for tenant recruitment.

Constraints to this phase are no different than the constraints to the site selection phase (formerly Phase One) within the GEIPDP's. For the sake of brevity, the constraints will not be relisted here; please refer to Section 3.1.3 – Phase One for details on these constraints.

3.2.5 – Additional Phase: Phase 6 – Delegation of Regulatory and Managerial Responsibilities – Formation of EIP Management Board

Phase 6 of the REIPDP represents a switch in decision-making authority: from the EIP development team to an EIP management board. It is important for the EIP development team to determine the structure (abilities and limitations) and personnel of the EIP management board and regulatory liaisons affiliated with the EIP. EIP development teams will create this body of management out of selected tenants' management board, members of the EIP development team itself, and regulatory agency members that played an important part in collaborating with the EIP during design and development. Through proper appointments, the EIP development team can ensure that the important decision-makers and stakeholders remain in positions of influence and can play a role in ensuring the longevity of the EIP. The EIP development team must be careful to determine what primary actors and decision-makers will continue to lead as management board members and which ones to phase out (Nolan, 2004). For this phase to lead to a successful EIP, it is important to have complete consensus from each member of the EIP (whether it be an auxiliary service provider, tenant, public service provider, or any other entity within the EIP) with respect to the delegation of managerial responsibilities, division of costs for shared infrastructure and services, and regulations and policies that the EIP inhabitants must abide by.

Constraints observed during the construction of a management board pertain to the size of the management board, management board members' experience with industrial ecology, and maintaining a balance of power between the EIP management board and tenant managers. The size of the management board acts as a constraint to this development process because the EIP does not want to deal with parallel management issues. This occurs when a too many managers from too many different organizations are involved in the overall management effort; involving more managers increases the potential for loss of consensus or management-caused operations conflicts (from lack of communication) (Koenig, 2005). The EIP development team must make sure each inhabitant within the EIP is represented on the management board, but must also factor in the maximum size of the management board constraint as well.

The second constraint to the formation of a management board is the management board members' potential lack of knowledge about industrial ecology. This can serve as a constraint because the management board is supposed to consist of innovative leaders that are constantly searching for symbiotic linkages between tenants or community groups. Since the management board must equally represent each tenant, there is a possibility for a management board member to lack experience in the practice of industrially ecological methods. This constraint will limit which individuals will be nominated for membership on the management board; those that are enthusiastic about finding new byproduct exchanges for their company to engage in and are willing to learn how to apply industrial ecology (e.g., environmental management system coordinators).

The third constraint is related to the assignment of the management board members' authority and responsibilities. The EIP development team must make sure that no one manager on the board is given too many (or too few) responsibilities or too much (or too little) decision-making authority, and vice versa. With respect to the rest of the park, the EIP development team must also develop a management board that makes sure the authority and responsibilities of each tenant's management team is not infringing on any other tenant's managerial authority and responsibilities. In the event that there is a conflict between two management groups belonging to two different tenant facilities, the EIP development team must have an internal governing system in place for deciding which party is at fault, which party needs to pay the consequences for its actions, and what those consequences will be. The EIP development team must develop a set of EIP covenants that defines all management level responsibilities (both for the EIP management board and individual management teams of each inhabitant), roles, codes of conduct, and conflict resolution system. These EIP covenants would apply to the EIP tenants, auxiliary service providers, and the management board during engagements with regulatory agencies, neighboring tenants, and the surrounding community members.

3.2.6 – Additional Phase: Phase Omega – Implementation and Construction

The final phase of the REIPDP is concerned with implementing the optimal layout (as determined in Phase Five) and initiating construction of the park facilities. The phase is numbered with the omega (or Ω), because this letter is the *last* letter in the Greek alphabet and, thus, is appropriate for the *last* phase in the REIPDP. Permits authorizing the industrial operations of EIP tenants must be granted by the EIP's regulatory agencies prior to tenant facility and infrastructural construction initiation. Upon authorization, each tenant will work closely with construction companies and other development personnel to decide how to apply green design initiatives to their facilities and infrastructure. At this point, the EIP development team is in the middle of transferring its authority and responsibilities to members of the EIP management board, and all (or nearly all) of the site preparation actions have been completed. In addition, any byproduct exchanges that have been formalized earlier on during the REIPDP will also be implemented. Now that each tenant has officially co-located into the EIP, the EIP management board must plan more industrial ecology-based design charrettes, trust-building social events, and community open house events to strengthen ties and further educate company decision-makers and stakeholders about the purpose of the EIP development project. In addition, this phase allows the EIP management board to begin implementing community improvement programs and industrial ecology education seminars to help build more support for the EIP and to further increase the societal bottom line.

The primary constraint to the implementation and construction phase pertains to regulations and policies included in the EIP covenants. The regulatory agency works in conjunction with EIP management to create rules for the inhabitants of the EIP. These rules may prohibit some processes or procedures that the tenant organization may be accustomed to performing at its former facilities. It is the EIP management board's responsibility to disseminate rules and regulations enforced by regulatory agencies to managers on the tenant level. These rules formalize expectations that were developed and shared with the tenants prior to their admittance into the EIP. These rules and regulations are generally established as early as Phase 0B or Phase 1 (depending on the EIP development team and Public Agencies knowledge about the goals, scope, principles, and guidelines for potential tenants as the EIP development project continues). Each Tenant's managers must then incorporate these rules and regulations into their own set of covenants to influence how they conduct their business practices and prove to the EIP development team that they can operate within these rules and regulations. This flow down of information is necessary to ensure the health and safety of the surrounding community groups and the environment. The regulations and policies should be seen as long term constraints that are necessary to control operations by each tenant at the EIP; they are constraints ensuring sustainable future development of the EIP, not just the implementation and construction phase.

3.3 – Validation of REIPDP against Analyzed EIP Development Processes

To ensure that it truly represents a standard for the development process used to create EIPs, the REIPDP was evaluated in two different ways:

1. A comparison between the decisions and actions contained in the phases of the REIPDP and the steps of the 21 EIP design processes was conducted and;
2. The decision-objectives belonging to the 21 EIP design processes (as well as the REIPDP's decision-objectives) were analyzed to determine how aligned they are with the TBL's means, low-level, and high-level fundamental-objectives.

The results to the comparison between the REIPDP and the 21 EIP development decision processes studied can be seen in Table 14. Following Table 14, Table 15 depicts the decision-objectives associated with each of the REIPDP's phases.

Table 14: Correspondence between REIPDP phases and steps in 21 EIP development decision processes studied

EIP Design Process #	Does the REIPDP Phase have Corresponding Steps in this EIP Design Process?							
	0A	0B	1	2	3	4	5	6	Omega
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes
4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
11	Yes	Yes	No	Yes	Yes	N/A, EIN	N/A, EIN	N/A, EIN	N/A, EIN
12	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
17	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
18	No	Yes	Yes	No	Yes	No	No	Yes	Yes
19	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
20	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Totals (Yes: 168, No: 17)									
Yes:	20	21	18	18	19	19	16	18	19
No:	1	0	3	3	2	1	4	2	1

Table 15: REIPDP Phases and the Decision-Objectives associated with each

Phase/Step Exercised	Objective(s) of Decision (What)
Phase 0A: Identify, involve, and establish primary actors internally (EIP development team) and externally (within local business (resource exchange network, industrial associations, etc.), regulatory agencies, and community) via regionwide social function (conference, meeting, symposium, etc.)	Identify role players; change agent can begin to "spread influence" and garner support from stakeholders. Funding for initial/pre-development activity (business surveys and conferences, community meetings, drafting of prelim. plans or guidelines, etc.) is typically provided by these decision makers
Phase 0B: Establish goal, scope, implementation strategy, principles, guidelines for potential tenants and proposal for development of region's "ideal" EIP. ALL stakeholders and decision makers should be in consensus by the end of this phase (Also called Terms of Reference)	Define scope of the EIP project - all stakeholders and decision makers will be offering ideas and concepts and consensus is eventually reached (guidelines and principles are developed). Feasibility studies are began to determine if project can achieve environmental, economic, and social equity. A proposal is also drafted to determine sources of funding and to advertise the EIP to prospective tenants
Phase 1: Develop Action Plan	Create an action plan that acknowledges challenges (use guidelines and principles to address), notes benefits, creates initial estimates (for land required and cost of infrastructure, utilities, etc.), and mentions possible sources of funding and why those entities would be interested (e.g. ROI, regional economic revitalization, job creation, environmental waste reduction, etc.). Also highlights roles and responsibilities of decision makers in the project
Phase 2: Brownfield/Greenfield site search and evaluation (More Detailed Feasibility Analysis of Region with respect to its Inhabitants and Resources). Followed up with Acquisition, and Preparation (includes site remediation, infrastructure and public services installation, and public facility	Determine where in region EIP can feasibly operate and maintain sustainable growth (i.e. Answer where the EIP will be able to achieve the triple bottom line?).

construction) after authorization	
Phase 3: Identify ideal industrial-cluster linkages with respect to chosen location (also consider required supporting non-industrial inhabitants) and projected anchor(s).	Identify which industrial clusters can be colocated in order to maximize economies of scale (i.e. profitable symbiotic linkages) and byproduct, energy, and/or water exchange, while minimizing waste creation. From this, a site-wide information management service could be created (e.g. EcoStar at Devens)
Phase 4: Identify, Evaluate and Secure inhabitant businesses for each industrial (and non-industrial support service) cluster	Screen and recruit businesses that can, upon entering, maximize benefit to (1) themselves, (2) others in the park, and (3) the community
Phase 5: Determine Optimal Layout - EIP Prototype Scenario Exploration	Determine layout that complements byproduct and energy exchange projects and maximizes the (1) economic, (2) environmental, and (3) sociological benefits created by the EIP
Phase 6: Organize and Determine regulatory and managerial responsibilities to be held by EIP management and regulatory agents	Determine structure (abilities and limitations) and personnel of EIP mgmt team as well as the regulatory liasons affiliated with the EIP. This will ensure that the critical stakeholders and decision makers during the development process will remain in positions of influence
Phase Omega: Implementation and Construction	Full development of EIP: construction of green design initiatives, finalization and initiation of industrial symbioses projects, and community improvement/education initiatives are begun here

The total number of mismatches between the steps performed during the 21 development processes and the phases in the REIPDP was reduced from 30 to 17. Thus, over the 21 development processes studied, there were 168 matches between the steps of these development processes and the REIPDP phases. This represents a 91% match in steps when they're compared to phases between the 21 EIP development decision processes studied and the REIPDP; an improvement by 12%

over the GEIPDP's match rate. This improvement indicates that the phases of the REIPDP contain phases that more accurately represent the steps performed during design and development decisions made during EIP projects. With a more accurate depiction of the development process used to design and develop EIPs, work can begin towards improving this development process by applying engineering decision-making methods and procedures.

3.4 – Determining how well the EIP Development Projects and the REIPDP Advance the Triple Bottom Line Objectives

After this comparison is made, an evaluation to determine how closely aligned each of the decision-objectives are with the objectives of the TBL was conducted. To be more specific, an evaluation was carried out to determine how well each of the EIP development processes' decision-objectives (as well as the REIPDP's decision objectives) advanced each of the TBL's means, low-level, and high-level fundamental objectives.

In order to assess how well a particular EIP development project will perform with respect to maximizing a region's TBL, the objectives of the EIP development decisions must be analyzed for alignment with the TBL objectives. To do this, a rubric was created to categorize and score the objectives of decisions made by EIP development teams during EIP development projects. Each decision objective in the EIP development process is evaluated with respect to two criteria: (1) how equally the decision's objectives attempt to advance the TBL's three high-level fundamental objectives and (2) their performance with respect to four attributes (as mentioned earlier in Section 2.3) (which will result in one overall “grade” per decision-objective). The TBL’s objectives (i.e., means, low-level fundamental and high-level fundamental objectives) are connected to the decision objectives based on whether the decision objective actually answers how the means objective it is attempting to connect to will be achieved or advanced. Recall in Section 2.3 that to move up the means objective chain (i.e., toward the fundamental objective), one must ask *why* the following means or fundamental objective is important. Conversely, to move down the means objective chain (i.e., away from the fundamental objective), one must ask *how* the following means or low-level fundamental objective is going to be achieved or advanced. The connections are represented by lines connecting the objectives. Please refer to Section 2.3, Figure 12, Figure 13, Figure 14, and Figure 15, to see the TBL’s high level, low level, and means objectives. The score for the four attributes for each development process’ step is determined from how well the step’s decision(s) (and their associated objectives) advance the connected TBL objectives. The scores for each of the four attributes reveal how aligned the development step is with the objectives that are focused on maximizing the region’s TBL. The four alignment attributes are as follows: (1) the number of TBL means objectives that the decision's objective are related to (or "connected" to); (2) the number of low-level fundamental objectives advanced by the means objectives. In some cases, the means objectives are those that were advanced by the EIP development team's decision objectives directly, and those means objectives are responsible for advancing the TBL objectives; (3) the strength of relevance between the decision's objective and the means objective(s) it addresses and; (4) the relevance between the means objectives and the low-level fundamental objectives they're connected to (i.e. connected via the means-objective chain that is initiated by a decision-objective). Justifications for the range of scores for each attribute are discussed in Table 16 through Table 19.

Table 16: Attribute 1's score scale and scoring rationale

ATTRIBUTE 1 - # OF CONNECTIONS BETWEEN DECISION-OBJECTIVES & TBL MEANS-OBJECTIVES	
SCORE	**SCORING RATIONALE**
1	**1** connection between decision-objectives and TBL means-objectives observed
3	**2** connections between decision-objectives and TBL means-objectives observed
5	**3** connections between decision-objectives and TBL means-objectives observed
7	**4** connections between decision-objectives and TBL means-objectives observed
9	**5** or more connections between decision-objectives and TBL means-objectives observed

Table 17: Attribute 2's score scale and scoring rationale

ATTRIBUTE 2 - # OF LOW-LEVEL FUND. OBJ. ADVANCED BY MEANS OBJECTIVES	
SCORE	**SCORING RATIONALE**
1	**1** low-level fundamental objective is contributed to by the means objectives that are advanced by the decision-objectives
3	**2** low-level fundamental objectives are contributed to by the means objectives that are advanced by the decision-objectives
5	**3** low-level fundamental objectives are contributed to by the means objectives that are advanced by the decision-objectives
7	**4** low-level fundamental objectives are contributed to by the means objectives that are advanced by the decision-objectives
9	**5** or more low-level fundamental objectives are contributed to by the means objectives that are advanced by the decision-objectives

Table 18: Attribute 3's score scale and scoring rationale

ATTRIBUTE 3 - RELEVANCE BETWEEN DECISION'S OBJECTIVES AND TBL MEANS-OBJECTIVES	
SCORE	**SCORING RATIONALE**
1	Very Low - decision is **not** aligned or is intended for procedural or administrative purposes
3	Low - objective of decision does **poor** job of addressing the TBL means-objectives it is connected to.
5	Medium - objectives of decision **indirectly** address the TBL means-objectives they're connected to adequately. Generally, a decision's objective indirectly addresses a means/fundamental objective by not primarily focusing on the means/fundamental objective in question; but the decision's objective is still related to that means/fundamental objective in some way).
7	High - decision contains multiple objectves. One decision objective **directly** addresses the TBL means-objectives it is connected to, but other decision objectives address different TBL means objectives (resulting in a decision that satisfies more than one means objective). Generally, a decision's objective directly addresses a means/fundamental objective by including keywords and phrases from the means/fundamental objective in its own objective statement
9	Very High - decision only contains one objective and that objective **directly** addresses the TBL means-objectives it is connected to. In other words, there are no other objectives to the decision that would address other means-objectives. A one to one correspondence between decisions and means-objectives reduces the chances for disagreement (or lack of consensus) between EIP development team members because there is no competition between decision objectives. More decision objectives leads to more competition for company resources, which dilutes the advancement of means objectives related to these decision objectives.

Table 19: Attribute 4's score scale and scoring rationale

ATTRIBUTE 4 -RELEVANCE BETWEEN TBL MEANS-OBJECTIVES AND LOW-LEVEL FUND. OBJECTIVES	
SCORE	SCORING RATIONALE
1	Very Low - means-objectives is not aligned with the low-level fundamental objectives
3	Low - means-objectives does poor job of addressing the low-level fundamental objectives it is connected to.
5	Medium - means-objectives indirectly advance the low-level fundamental objectives they're connected to.
7	High - means-objectives directly address the low-level fundamental objectives they're connected to and within a short-term time horizon (e.g. 5 years).
9	Very High - means-objectives directly address the low-level fundamental objectives they're connected to and within a long-term time horizon (e.g. 100 years).

To determine the 21 EIP development projects' scores with respect to each attribute, each of the documents pertaining to the EIP development processes was carefully read and analyzed for how, or even if, each decision made and each action item taken during each development process was contributing to the advancement of the TBL's means objectives and low-level fundamental objectives. The "Why is that Important?" test (i.e., WITI test) was performed to determine why the completion of a decision's objective needs to be accomplished in order to advance one or more of the TBL's objectives (Daft, 2001). When the connections (either indirect or direct) between the EIP development project's decision objectives and the TBL's objectives are more relevant, the region's TBL will be advanced further, and the EIP will be more beneficial for the region. Once it was established that a step's objective is contributing to one of the TBL's objectives, a connection has been made, and a means-objective chain has been initiated. The TBL fundamental-objectives hierarchy (seen in Section 2.3; Figure 12, Figure 13, Figure 14, and Figure 15) shows several different opportunities for means-objective chains; once a decision-objective advances one (or more) of the TBL objectives initially, a domino effect occurs between TBL means-objectives until the high-level fundamental objective is advanced. One example of a means-objective chain can be seen in Table 20 from EIP development process #9.

Table 20: A means-objective chain created from the TBL's fundamental and means objective hierarchy (in tabular form – adapted from EIP Process #9)

Phase/Step Exercised	Objective(s) of Decision (What)	Means-Objectives	Low-Level Fundamental Objectives Advanced		High-Level Fundamental Objective Advanced
7. Siting and Massing	7.4 Minimize overall development footprint by considering stackable or alternative warehousing techniques, use of joint logistics facilities, and building clustering	→	Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Minimize cost of utilities to tenants and community	Maximize economies of scales and scope for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
			Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		→	Maximize energy-usage efficiency		Maximize Environ. Bottom Line

Though some objectives may appear more than once, they are not double counted when determining the score for attributes one and two. Rather, the repeating of an objective represents how more than one means-objective chain is advancing the same objective; an overlap in means-objective chains is occurring. The arrows contained within a cell appear whenever a decision objective directly advances a low-level fundamental objective without advancing a means-objective beforehand. The means-objective chain begins with the EIP development processes' decision-objective. These decision objectives are derived from publications that were released by decision makers associated with the EIP development project. These decision objectives are then analyzed to see why they're important (i.e., the WITI test) so the decision objective in question can be connected with the appropriate TBL means-objective (i.e., the TBL means-objective that the decision objective in question answers "how" the TBL means-objective can be accomplished or advanced). These TBL means objectives are then connected to other TBL means objectives and fundamental objectives that are relevant to the decision objective that started the means-objective chain. An example of the progression from the decision-objective to the TBL means objectives and up to the TBL high level fundamental objectives can be seen with respect to Devens EIP (EIP #8) in Figure 19.

In addition, the attributes need to be given weights of importance so that each decision-objective's score can be calculated. First, the attributes are ranked in order of importance. This ranking can be seen in Table 21.

Table 21: Ranking of attributes that are used to determine a Criterion 1 grade.

Attribute Initial Ranking of Importance	
1st	Attr. 2 - # of Low-Level Fund. Obj. Advanced by Means Objectives
2nd	Attr. 4 - Relevance Between TBL Means-Objectives and Low-Level Fund. Objectives
3rd	Attr. 3 - Relevance Between Decision's Objectives and TBL Means-Objectives
4th	Attr. 1 - # of Connections Between Decision-Objectives & TBL Means-Objectives

These rankings demonstrate that the TBL fundamental hierarchy may not be comprehensive (hence, a low ranking of attribute 1 since it scores how many TBL means-objectives are connected to by decision-objectives) and that relevance is equally as important as the number of connections made. From these rankings, the Analytic Hierarchy Process (AHP) can be used to determine the weights of each attribute; a pairwise comparison and a pairwise comparison matrix are used to determine the weights for each alignment attribute. The pairwise comparisons and pairwise comparison matrix can be seen in Table 22.

Table 22: Pairwise Comparisons and the Pairwise Comparison Matrix

Pairwise Comparison of Attributes		
Attr. X	**Attr. Y**	**Comparison Score**
Attr. 1	Attr. 2	0.143
Attr. 1	Attr. 3	0.333
Attr. 1	Attr. 4	0.200
Attr. 2	Attr. 3	5.000
Attr. 2	Attr. 4	3.000
Attr. 3	Attr. 4	1.000

(A)

Pairwise Comparison Matrix of Attributes							
Attributes	Attr. 1	Attr. 2	Attr. 3	Attr. 4	Geometric Mean	Normalized Weight	Consist. Ratio
Attr. 1	1.000	0.143	0.333	0.200	0.312	0.056	0.0393
Attr. 2	7.000	1.000	5.000	3.000	3.201	0.579	
Attr. 3	3.000	0.200	1.000	1.000	0.880	0.159	
Attr. 4	5.000	0.333	1.000	1.000	1.136	0.205	
				TOTAL:	5.530	1.000	

(B)

The consistency ratio was calculated by finding the largest eigen value of the pairwise comparison matrix and measuring the degree of consistency (also known as the consistency index) via the following equation:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \qquad (1)$$

Where: λ_{max} = the largest eigenvalue of the pairwise comparison matrix and;

n = the size of the pairwise comparison matrix

The consistency ratio is found by dividing the CI by the appropriate random consistency index (RI) value. The appropriate random consistency index value depends on the size of the pairwise comparison matrix (i.e., the value of n) and its range of values can be seen in Table 23.

Table 23: Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this case, the RI is equal to 0.9 since there's four attributes. Notice the consistency ratio is low (i.e., 10% or lower), so the weighting of these attributes is acceptable. A weighted sum is calculated from these four attributes and their weights to determine each decision's score (which can be seen in Table 22-B). To calculate the weighted sum, which is the decision-objective's score (ranging from 1 – 9), multiply the attribute score by the appropriate attribute weight. Once these four terms are calculated, sum them together, and the decision-objective's score is determined. Next, the decision process step in question is given a score based on the weighted sum of four attribute scores. The score represents the degree of alignment that the process step's decision-objectives have with respect to the TBL objectives. Justifications for each attribute score are presented and can be seen for the same example as earlier (i.e., EIP development process #9) in Table 24.

Table 24: Attribute scores received by EIP development process #9's Phase 7 and the scoring justifications per attribute

Attribute 1 Score	Attribute 2 Score	Attribute 3 Score	Attribute 4 Score	Decision Objective's Score (out of 9)	Scoring Justification
1	9	5	7	7.5	Attr. 1: 1 connection between the decision's objective and the TBL means-objective was observed Attr. 2: 5 low-level fundamental objectives are advanced by the means objectives (that are advanced by the decision-objectives) Attr. 3: objective of decision indirectly address the TBL means-objectives it is connected to adequately Attr. 4: means-objectives directly addresses the low-level fundamental objectives it is connected to and within a short-term time horizon

These scores represent how well, or how poorly, Step 7 (of EIP development process #9's Phase 7) contributes to the region's TBL. The scores from all the steps are then aggregated (similar to how one would determine their grade point average, except on a scale of 9.0 instead of 4.0) to determine the EIP's development process grade. This grade reflects each EIP development process' performance with respect to Criterion 2 (see Table 25). To be considered as a development process that is aligned with the TBL, this grade must be 75% or higher. 75% was chosen because this value represents average quality (i.e., a "C" is a 75% passing grade). Thus, in our example with EIP development process #9, the overall grade was a 71.7%, so this EIP development project would (barely) be considered unaligned with the TBL's objectives.

Criterion 1 (see Table 25) describes how equally each EIP development process' decision advances the TBL's three high-level fundamental objectives. Ideally, each EIP development process would utilize one-third of its decisions to advance the environmental bottom line, another one-third to advance the societal bottom line, and the remaining one-third to advance the economic bottom line. Each decision's objective is capable of advancing more than one high-level fundamental objective. The closer the EIP development process is to dedicating its decisions to each of these three bottom lines equally, the more aligned the EIP development process will be considered. A deviation of +/- 5% is allowable, so, to be considered a "well aligned" EIP development process, any one TBL high-level fundamental objectives must not be advanced more than 38% of the time, or less than 28% of the time by the time the EIP development project has concluded. In addition, evaluation of the REIPDP was conducted, even though it is untested as an EIP development process, because it contains decision objectives and constraints like the 21 EIP development processes that were studied. Actual distributions of the 21 EIP development processes with respect to the three high-level fundamental objective of the TBL can be seen in Table 25.

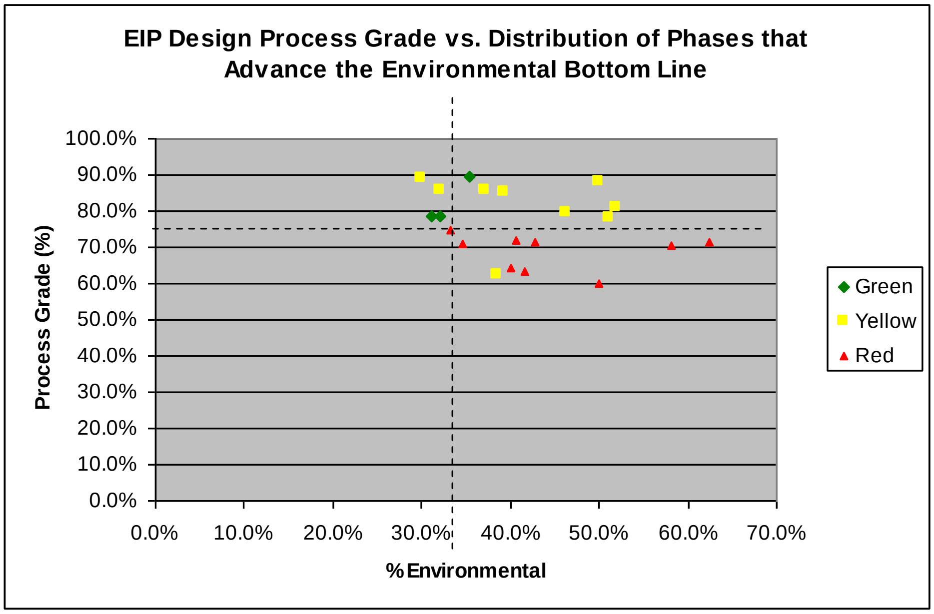
Table 25: Performance of EIP development processes with respect to Criteria 1 & 2.

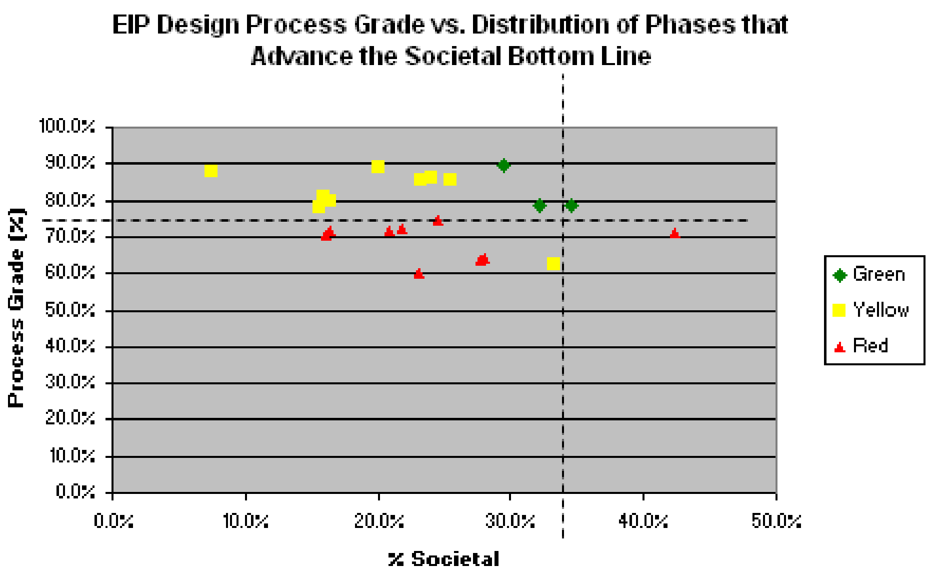
EIP Design Process #	# of Phases Under Consid-eration	# of Times High-Level Fundamental Objective is Advanced by Means-Objective Chain			Criterion 1: Distribution of the TBL High-Level Fund. Objectives that are Advanced by the EIP Development Steps			Criterion 2: EIP Dev. Proc. Grade
		Environmental Bottom Line	Societal Bottom Line	Economic Bottom Line	% Environ.	% Societ.	% Econ.	
REIPDP	8	24	20	24	35.3%	29.4%	35.3%	89.7%
13	6	9	10	10	31.0%	34.5%	34.5%	78.5%
15	6	9	9	10	32.1%	32.1%	35.7%	78.6%
2	12	27	4	23	50.0%	7.4%	42.6%	87.9%
4	12	15	13	11	38.5%	33.3%	28.2%	62.5%
10	14	31	11	25	46.3%	16.4%	37.3%	79.6%
11	4	8	6	11	32.0%	24.0%	44.0%	85.9%
12	7	16	10	17	37.2%	23.3%	39.5%	85.8%
14	11	23	7	15	51.1%	15.6%	33.3%	78.2%
17	8	20	13	18	39.2%	25.5%	35.3%	85.3%
18	4	13	4	8	52.0%	16.0%	32.0%	80.9%
19	6	12	8	20	30.0%	20.0%	50.0%	89.2%
21	9	16	17	14	34.0%	36.2%	29.8%	73.2%
1	11	13	6	7	50.0%	23.1%	26.9%	60.0%
3	6	10	7	8	40.0%	28.0%	32.0%	64.1%
5	20	27	18	20	41.5%	27.7%	30.8%	63.3%
6	10	13	7	12	40.6%	21.9%	37.5%	72.0%
7	10	15	11	19	33.3%	24.4%	42.2%	74.6%
8	9	30	10	8	62.5%	20.8%	16.7%	71.5%
9	12	21	8	20	42.9%	16.3%	40.8%	71.7%
16	9	18	5	8	58.1%	16.1%	25.8%	70.5%
20	18	27	33	18	34.6%	42.3%	23.1%	71.1%
EIP Design Processes' Avgs:	10	18	10	15	42.3%	23.5%	34.2%	75.3%
		% Deviation from the Desired Values (negative % = too low and positive % = too high)		Average of EIP Design Processes:	9.0%	-9.8%	0.8%	0.3%
				REIPDP:	2.0%	-3.9%	2.0%	14.7%

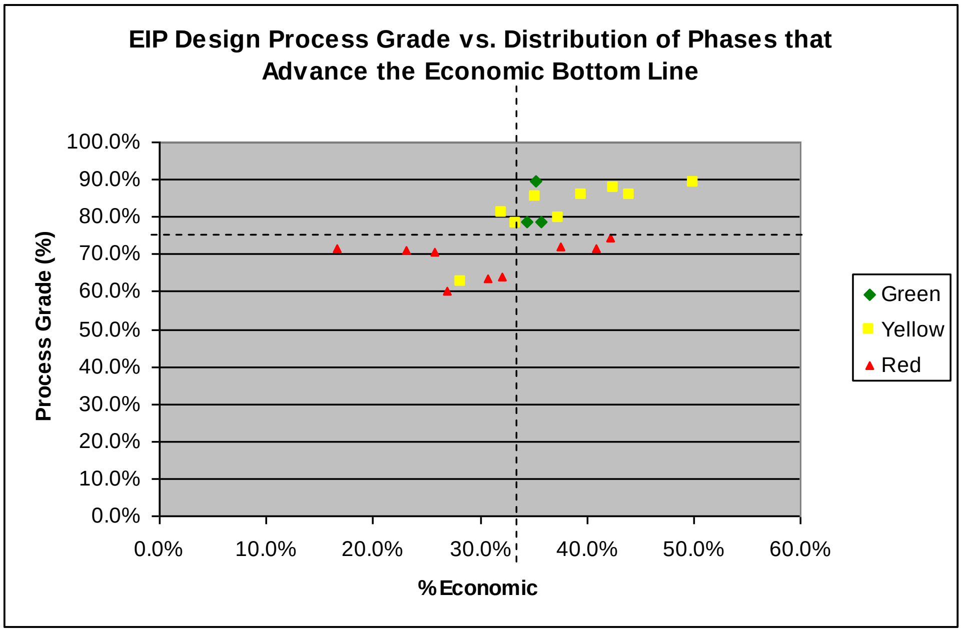
The combination of these criteria puts each EIP development process into one of three categories: (1) green for the processes that satisfy the criteria, (2) yellow for processes that only satisfy one criterion, and (3) red for processes that satisfy neither criterion. Only two of the studied 21 EIP development processes could be considered "well aligned," since they're the only ones to satisfy both criteria for TBL alignment. As this evaluation set out to demonstrate, the REIPDP serves as an improvement on existing EIP development processes because it possesses a grade well above 75% and has a fairly even distribution of phases whose decision-objectives advance all three TBL high-level fundamental objectives (see **Error! Reference source not found.**). The last two rows in this table demonstrate that the REIPDP performs well above the average EIP development process when considering the percent deviations from the desired values.

Three scatter plots are contained in Table 26. These scatter plots show how each EIP performs with respect to Criterion 2 and Criterion 1 (i.e., each of the three TBL high-level fundamental objectives – one scatter plot per objective). The green points represent the EIP development projects (two plus the REIPDP) that satisfy both criteria. The yellow points represent the EIP development projects that satisfy only one criterion. Lastly, the red points represent the EIP development projects that did not satisfy either criterion. Observing from the low number of EIP development projects that are "well aligned" (i.e., green points in Table 26) demonstrates how difficult it is for EIP development projects to substantially advance the TBL's objectives in a manner that accommodates the environment, economy, and community equally.

Table 26: Scatter Plots Showing EIP Development Process Grades versus Distribution of Phases that Advance the TBL's High-Level Fund. Objectives







From this evaluation, and the comparison conducted earlier, it is safe to say that the REIPDP can serve as an all encompassing standard for EIP development processes, and it is an improvement over the GEIPDP. To show that the REIPDP is aligned with the triple-bottom line maximization objective, a fundamental & means objective network was created. The fundamental & means objective network of the REIPDP can be seen (in tabular form) in Table 43 through Table 46 of the appendix.

Chapter 4: Determining Decision-Based Design Methods for Phases of the Revised EIP Development Process

Chapter 4 will demonstrate decision based design techniques that can be used to ensure that the REIPDP is being executed properly. In a broader sense, what Section 4.1 will discuss can be applied to more than just the REIPDP. After introducing the Contingency Decision Making Framework and how it works, Section 4.2 discusses how it can be used to analyze each of the phases in the REIPDP in order to determine the appropriate decision making procedure for each phase. The existence of technical knowledge and problem consensus can vary from one EIP development team (and the project personnel that they work with) to another, but the generalizations made in Section 4.2 with respect to possession or lack of technical knowledge and problem consensus are implied from the documents pertaining to the 21 EIP development processes.

4.1: The Contingency Decision-Making Framework: Classifying Decision-Making Problems and Determining the Appropriate Decision-Making Procedure

A Contingency Decision-Making Framework (CDMF) is used by decision-makers who must find the solution to a complex system of problems, but are unsure which decision-making approach to apply to the problem system. The CDMF brings together the two dimensions of problem consensus and technical knowledge to help decision makers determine the nature of their problem, and choose a suitable decision-making problem to solve it (Daft, 2001). The CDMF is represented in Figure 20.

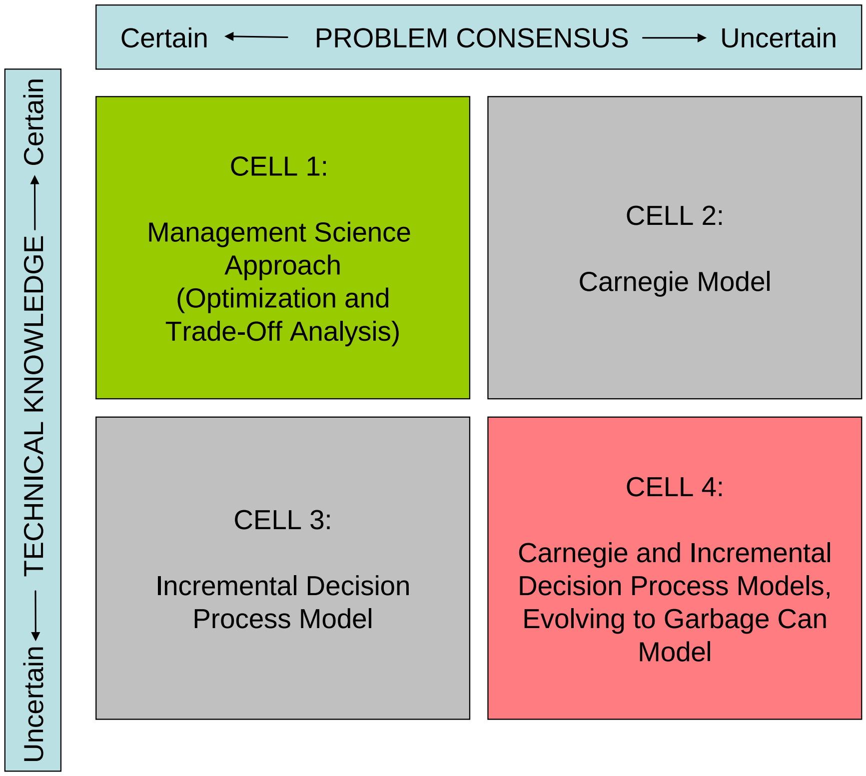


Figure 20: Contingency Framework for using Decision Making Methods (Daft, 2001)

The cells in Figure 20 correspond to different decision-making scenarios. In cell 1, both technical knowledge and problem consensus are present. A decision-making problem that fits into this category will yield a rational solution because the nature of the problem is agreed upon by decision makers and the cause-effect relationships are understood (leaving little room for uncertainty). Because of the degree of understanding for this type of problem, alternatives can be identified and analyzed for their expected benefit as a solution, and the probability that they will actually achieve the intended result. If presented as a decision-making problem of this sort, the EIP development team would employ the Management Science approach because this type of problem is open to mathematical analysis. With variables that can be identified and measured, application of optimization and trade-off analysis would yield a rational solution; goals can be represented as an objective function and the information pertaining to the limits of the variables can be translated into constraints (Daft, 2001).

In cell 2 the decision-making problem exhibits a lack of consensus (due to a high level of uncertainty), but technical knowledge about how to solve the problem exists. The Carnegie model can be used to reduce ambiguity and add consistency to the goals of multi-disciplinary decision-makers on the EIP development team. Coalition building is a useful way to achieve consensus, but does not always result in consensus between decision makers. If consensus cannot be reached, coalition building will lead to satisficing (i.e., choosing the earliest available alternatives that achieve a "satisfactory" level of performance, rather than a maximum one) and problemistic search (i.e., simple search procedures to find a satisficing solution rather than an optimal one) during decision-making periods where time will not permit bargaining and discussion. However, during some situations, debate, discussion, and eventual bargaining will be required. The coalition building event during the Carnegie model establishes the critical factors governing the problem at hand, the problem priorities, and leads to support for an agreed upon direction to move in to attain a solution. An example of the choice processes used during the conducting of the Carnegie model can be seen in Figure 21. The opportunity cost of having to establish consensus is the forgone attention and action with respect to other issues. Establishing a small number of coalitions (i.e., getting as close to problem consensus as possible) between decision-makers is especially important during the problem identification routine because it will provide clear standards and expectations for performance (Cyert and March, 1963; March and Simon, 1958; Daft, 2001).

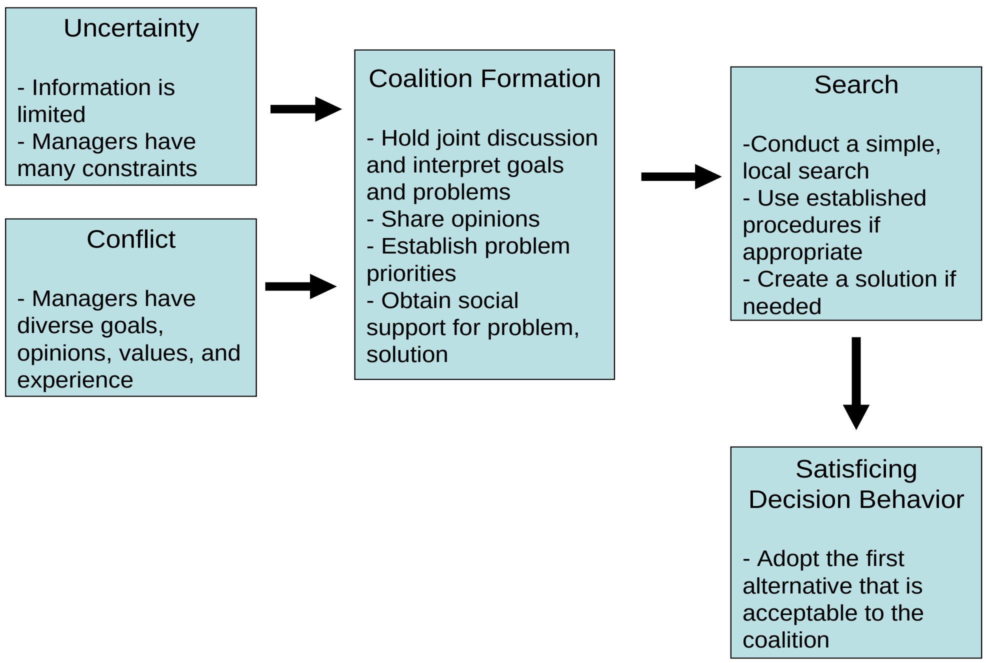


Figure 21: Choice Processes in the Carnegie Model (Daft, 2001)

In cell 3 are decision-making problems where problems and standards of performance are certain (i.e., problem consensus is present), but the techniques to solve the problem are ill defined and poorly understood by the decision-makers. Decision-makers can employ the Incremental Decision Process model to identify a problem and perform a series of small steps that will enable the decision-makers to learn a solution. Through the use of nested loops, new problems that arise can be handled by cycling back to an earlier routine within the Incremental Decision Process and evaluating in a time consuming step-by-step manner. After sufficient experience has been gained by the decision-makers, a method for solving the problem(s) at hand will form and the goals can be accomplished (Daft, 2001).

In cell 4 are decision-making problems where both problem consensus and technical knowledge do not exist. Under these circumstances, logical decision sequences starting with problem identification and ending with a bounded rational solution will not happen. Instead, potential solutions will appear before a problem has even surfaced and, with a lack of experience on the matter, no one can predict whether these potential solutions will lead to the desired outcome. A combination between the Carnegie and Incremental Decision Process models must be utilized on a decision by decision basis to continually build consensus and introduce new techniques for solving the problems present. The garbage can model can then be used to organize decisions into four "streams" of concurrent events; problems, participants, potential solutions, and choice opportunities. As one stream produces a decision, the information derived from this initial decision will interact between the other four streams and eventually lead to the generation of decisions in those streams as well (Daft, 2001; Cohen et al., 1972).

Before Phase 0A of the EIP project begins, the project initiators are not clear what characteristics of an EIP would constitute a bounded rational solution; in other words, the project initiators lack technical knowledge to find a solution. On the other hand, the project initiators have agreement amongst its members as to what the problem is and what the goals and outcomes to pursue are (though in a fairly high-level and general way). An exemplary high-level outcome reads as follows: the design and development of an EIP that will enhance the region's triple bottom line. According to the CDMF, the project initiators possess consensus, but lack technical knowledge, leading them to the application of the Incremental Decision Process. The

Incremental Decision Process is the same as the Strategic Decision Process; both introduced by Mintzberg et al. (1976). The sub-problems created to represent each phase in the REIPDP are decision making problems that can be examined with the CDMF. Hence, the REIPDP can be considered as a decision making application of the incremental decision-making approach.

4.2: Selection of Decision-Making Procedure for each Phase in the Revised EIP Development Process

The EIP development team must select the correct decision-making procedure to enable them to conduct each phase of the REIPDP in a timely manner and to take advantage of problem consensus or technical knowledge amongst the decision-makers if either exists. Each phase is a decision-making problem and the EIP development team possesses technical knowledge and consensus, possesses just one of these variables, or is seeking to acquire both of these variables. A summary highlighting the presence of technical knowledge and problem consensus with respect to each phase is presented in Table 27. Once the presence (or absence) of technical knowledge and problem consensus is established for each phase, the CDMF can be referenced to determine the appropriate decision-making method to utilize to evaluate the respective sub-problem.

Table 27: REIPDP Phases and Presence/Absence of Technical Knowledge and Problem Consensus

Phase	Technical Knowledge?	Problem Consensus?	Decision-Making Method
0A - Identify, involve, and establish primary actors internally (EIP development team) and externally	Yes	Yes	Optimization
0B - Establish goal, scope, implementation strategy, principles, guidelines for potential tenants and proposal for development of region's "ideal" EIP.	No	Partially/No	Carnegie Model and Incremental Decision Process
1 - Develop Action Plan	Yes	Yes	Optimization
2 – Brownfield/Greenfield site search, evaluation, acquisition, and preparation	Yes	No	Carnegie Model
3 – Identify ideal industrial-cluster linkages	Yes	Partially/No	Carnegie Model
4 – Identify, evaluate, and secure inhabitant businesses	No	No	Carnegie Model and Incremental Decision Process
5 – Determine most beneficial layout w/ respect to EIP inhabitants	No	Yes	Incremental Decision Process
6 – Organize and determine regulatory and managerial responsibilites	No	Yes	Incremental Decision Process
OMEGA – implementation and construction	Yes	Yes	Management Science Approach (Trade-off analysis)

4.2.1: Decision-Making Process of Phase 0A

During Phase 0A, project initiators develop a set of requirements pertaining to project partners that can be transformed into a set of criteria. The project initiators can then hold recruiting events aimed at identifying and gathering information about the regional "green" leaders that would make ideal project partners (based on their predetermined criteria). At this phase in the decision process, the project iniators possess technical knowledge because they are able to develop criteria enabling them to rate and rank alternative project partners against one another and are able to determine the characteristics of a desired set of project partners (i.e., what the solution or preferred outcome should look like).

The goal of the EIP project is to enhance the triple bottom line of the region, and the project initiators will try to recruit project partners that understand the means necessary to accomplish this goal. Overall consensus is good, but consensus with respect to what the problem is and what the goals and outcomes of the phase should be is necessary as well. Members of the project initiating entities build consensus while deciding what the project partner criteria are and while deciding the relative important of the criteria. Since both problem consensus and technical knowledge exist, the CDMF implies that the project initiators can employ a management science approach to carefully determine the project partners (i.e., the sub-solution) that will help them develop a successful EIP (i.e., the primary solution).

4.2.2: Decision-Making Process of Phase 0B

During the decision-making process to Phase 0B, the EIP development team lacks technical knowledge. The EIP development team needs to analyze the data gathered during Phase 0A and determine what relevant performance metrics to use to evaluate the EIP project's feasibility; determine which proposed concepts to incorporate in the feasibility study; search for feasibility studies with similar intentions and imitate the relevant methods; and determine a basis for estimating the parameters that will be used in the proposal for investors.

In addition to a lack of technical knowledge, the EIP development team will need to build consensus between its members, the interested industrial associations, regulatory agencies, and community groups in order to develop a set of goals, the scope, an implementation strategy, principles and guidelines for the development of an "ideal" EIP. Since so many different parties are involved, coalition building will play an important role in arriving at a solution to this decision-making process. This phase essentially puts all internal and external primary actors in alignment, but not necessarily in a sequential manner. With a lack of consensus or technical knowledge, the CDMF suggests the use of the garbage can model in order to generate solutions meeting each of these four objectives.

4.2.3: Decision-Making Process of Phase 1

During the decision-making process to Phase 1, the EIP development team needs to avoid repeated development processes that will not yield any new information, maximize the information flow streams between primary actors, and delegate roles and responsibilities that take advantage of the experience of primary actors. Substantial progress on the feasibility study started in Phase 0B can provide detailed technical knowledge to help the EIP development team determine what concepts will help achieve a good triple bottom line and should be incorporated into the action plan. In addition, coalition building around the establishment of goals, scope, an implementation strategy, principles, and guidelines for the EIP that occurred in the previous phase will benefit the EIP development team in reaching consensus on what needs to be included in the action plan. With problem consensus and technical knowledge in existence, the CDMF directs the EIP development team to employ a management science approach to the development of the action plan. Use of trade-off analysis will be important to strategically allot roles and responsibilities to primary actors and to integrate these roles and responsibilities with a reliable schedule for the EIP project.

4.2.4: Decision-Making Process of Phase 2

During the decision-making process to Phase 2, the EIP development team needs to work with the public agency to identify sites that already have industrial zoning permits, or will be able to receive industrial zoning permits without extra effort. Technical knowledge is present because the EIP development team can rely on knowledge learned during the feasibility study and information used to develop the proposal to determine which sub-regions contain a sustainable amount of resources applicable to the industries present within the region. The search routine is agreed upon by all members of the EIP development team, so technical knowledge can be said to exist. Since there are a number of different disciplines represented on the EIP development team, the primary source of disagreement will probably be with regard to the criteria (and their associated weights) to use in identifying a suitable EIP site. Coalition building will play an important role in ensuring that too much compromise is not made in determining these criteria; each member of the EIP development team must try to remember that the ultimate goal of the project is to maximize the triple bottom line. Since technical knowledge is present, but consensus may be absent, this decision-making process falls into the category of Cell 2 of the CDMF. Thus, the EIP development team should apply the Carnegie model to achieve a suitable solution to this decision-making process.

4.2.5: Decision-Making Process of Phase 3

During the decision-making process to Phase 3, the industrial associations will play a role in informing the EIP development team about which industries they anticipate will have the greatest probability of forming byproduct exchanges between one another. The regulatory agency will assist in suggesting what industries won't have an easy time acquiring zoning permits or that may not match the available workforce's skill set. Technical knowledge exists because the EIP development team understands and agrees about how to identify the suitable industrial clusters. Constraints provided by the regulatory agency and industrial associations will help limit the options and define the criteria that the EIP development team will use to evaluate potential industrial clusters. In order to gain consensus between these planning agents and the community groups, more community meetings and workshops will need to be implemented. These community reach-out events will help the EIP development team form a better definition of the available workforce's limitations and will build community support for the EIP project if it does not yet exist. If the EIP development team possesses technical knowledge and is in consensus internally (i.e. between development team members), then they should attempt a management science approach to determine the most suitable industrial clusters for the EIP. However, if consensus is not attained early enough between the EIP development team and the community groups (e.g., the proposed industrial clusters are not accepted by the community groups), then the Carnegie model will have to be employed to discuss and debate problems the community groups have with the proposed industrial clusters, and to arrive at suitable alternative industrial clusters that are more agreeable with the surrounding community.

4.2.6: Decision-Making Process of Phase 4

Even though the decision-making process to Phase 4 is accompanied with a large body of knowledge coming from the potential tenants (via surveys and recruiting events), there is still a large degree of uncertainty concerning how any one tenant will interact with the other tenants to produce useful byproduct exchanges and co-exist within the EIP without conflict. At this point, the EIP development team is not in possession of technical knowledge because they need to establish the decision-making process priorities and a method for evaluating the alternatives. The decision-making process priorities include criteria (and criteria weights) that will be used to evaluate the potential tenants, and the determination of constraints. Coalition building must be utilized by the EIP development team to define the problem characteristics and to develop a method for evaluating each tenant without knowing who the other tenants will be. Consensus between the EIP development members will be gained once these criteria for the alternatives are defined and the goal of the EIP is reinforced in a manner that can be implemented. Since neither technical knowledge nor problem consensus exists, the decision-making process is categorized under Cell Four, and the Garbage Can model should be employed.

4.2.7: Decision-Making Process of Phase 5

During the decision-making process to Phase 5, the EIP development team will be presented with a number of different parameters and metrics to use that will help them define a solution space and relevant constraints, but how to use the available knowledge from all the previous decision-making process' results and account for uncertainties must still be determined. Technical knowledge is absent because the EIP development team still needs to determine how it will model different conceptual layouts and evaluate them for how well they can maximize the triple bottom line. In contrast, problem consensus does exist because the goals, principles, and guidelines of the park (defined much earlier) will make it clear to the EIP development team members that the ideal tenant will contribute to the improvement of the regional triple bottom line. According to the CDMF, with consensus present but a lack of technical knowledge, the decision-making process is categorized into Cell Three, and the Incremental Decision Process model should be used. The design routine will be used in conjunction with the evaluation of choice routines most. In addition, the EIP development team should expect a number of new option interrupts coming in the form of new industrial tenants looking to join the EIP, or auxiliary service providers that see an opportunity to help maximize the triple bottom line.

4.2.8: Decision-Making Process of Phase 6

During the decision-making process to Phase 6, the EIP development team is in a good position because consensus exists; the team knows they need to form a management board that will include primary internal and external actors who contributed the most to the effort of developing the EIP and are most knowledgeable about industrially ecological practices. However, technical knowledge pertaining to the exact roles, responsibilities, size of the management board, and distribution of current EIP development team members that should be converted into EIP management board members may still be an open item. The EIP development team can gain technical knowledge about how to construct an EIP management board by consulting other existing EIPs that employ a management board and researching how the assembled it (i.e., imitation). According to the CDMF, a decision-making problem containing problem consensus, but lacking technical knowledge should be approached with the Incremental Decision Making model.

4.2.9: Decision-Making Process of Phase Omega

During the decision-making process to Phase Omega, consensus exists between the EIP management board and the tenants because the goals, principles and guidelines layout what each tenant should be striving to attain. In addition, technical knowledge exists because the EIP management board is well versed in implementing green design methodologies, conducting analyses to verify whether a byproduct exchange will be beneficial and how to implement it, and in holding community reach-out events that will garner their support further. In the event that a decision-making process exhibits both consensus and technical knowledge, the CDMF suggests a management science approach. Trade-off analysis and optimization can be utilized to determine the lowest cost ways to implement green design initiatives and installation of infrastructure for byproduct exchanges. It is important to realize that the number of variables and constraints involved may make optimization infeasible;

the bounded rationality of the decision makers requires separating this phase into a number of different decisions (Herrmann, 2010). With an effective solution to this decision-making process, the EIP management board will conclude the REIPDP with the grand opening of an EIP that will without a doubt improve the triple bottom line of the surrounding region.

The CDMF is a very useful tool for analyzing the key decisions made during each phase of the REIPDP. By considering the development team's possession of consensus and technical knowledge (or lack there of), the correct decision-making method can be applied to the phase in question. EIP development teams need to recognize the guidance that the CDMF provides and begin benefiting from the utilization of the correct decision-making methods. The utilization of the correct decision-making methods will only reduce development time and support some of the economic TBL objectives. It is important to note that the discussion in this chapter is based upon the REIPDP and the understanding gained after studying 21 EIP development processes. However, more work is needed to corroborate these conclusions. This would entail application of the REIPDP, in conjunction with the CDMF, to at least one EIP development project. After a development project with objectives that are well aligned with the TBL's objectives is constructed and operational, the region where the EIP resides would need to be monitored for at least a short term time horizon (e.g., 5-10 years). This monitoring would enable an evaluation that determines how well the EIP (and the development process used to design and develop that EIP) helps benefit the region's TBL in actuality.

Chapter 5: Deciding which Tenants to include in Oak Point EIP – A Detailed Example of Phase 4

Often, Phase 4 of the REIPDP is lacking in consensus and technical knowledge, so coalition building and the incremental decision-making process should be implemented to bring about an ideal solution. There are exceptions, however. At Oak Point EIP, for example, a consensus as to what the EIP development team wanted was present (and is spelled out through the goals and requirements), however, the method for determining the most suitable tenants for entry into the EIP was not (i.e., technical knowledge was absent). When problem consensus exists, but technical knowledge is absent, the CDMF leads the EIP development team to employ the Incremental Decision Process model. Thus, in the following example, the incremental decision making method described by Mintzberg et al. (1976) is used to describe how one could decide which candidate tenants to recruit into the Oak Point EIP of South Bronx.

5.1 Assumptions

Data (mostly from 2005) used within assumptions was attained from "Sustainable South Bronx Eco-Industrial Full Feasibility Study" Byron et al., (2007). For the purposes of analysis, the following assumptions have been made.

- The operations at each facility are occurring at 100% capacity for the potential tenants under consideration.
- The work year consists of 250 days.
- "Marketable" outputs are recyclable products ready for resale (i.e. no further reprocessing is needed before consumer use; product may not necessarily consist of recycled feedstock or byproducts).
- "Byproducts" are recyclable products that may or may not require reprocessing before its use as a feedstock, an energy source, etc. by other tenants or business community (this content would end up in landfills or hazardous waste treatment sites if not recycled).
- Incoming and Outgoing production values for the Paper Converting Operation and Wood Salvage and Re-milling Operation rely on a full production scenario (which Byron et al (2007) estimates will take 3 years).
- Normal commercial trash generated by the Paper Converting Operation and Wood Salvage and Re-milling Operation is assumed to be produced at a rate between 1 and 2 tons/year (requiring one rail hopper car per year). This trash represents employee lunches, bathroom wastes, film plastic pallet wrap, and other small pieces of garbage.
- Decision-makers place high value on diverting waste from Bronx waste management system to nearby recycling facilities and demanding markets - this will be reflected within the criteria pair-wise comparison.
- An input material flow of 77,870 tons/year of 2" glass cullet serves as the fixed amount of glass recovered from the curbside recycling program and sent to the glass powder manufacturing facility.
- Since the Glass Powder Facility has the option of transporting its glass powder product via rail (nationally) and trailer (regionally/locally), I assumed equal utilization of each transportation method (i.e. each transportation method distributes exactly half of the total glass powder product).
- Assume the Paper Converting Operation recycles its normal commercial trash and pallets at only 50% efficiency; one of the two tons of waste produced per year gets recycled
- The recycled ferrous and non-ferrous metals are assumed to be reprocessed and redistributed to national markets via rail and road equally (i.e. 100 tons/year transported by road, and 100 tons/year transported by rail)

5.2 - Identification Phase: Determining Decision-Makers and Stakeholders

In the beginning of the decision-making procedure, it is important to declare exactly who the decision-makers and stakeholders are. The participants and their roles (as stakeholders or decision-makers) during each design phase vary. For the tenant nomination phase, typical decision-makers and stakeholders are as follows:

- Developers (still need to recruit);
- Investors and Preparers of Feasibility Study: Sims Hugo Neu Corporation, Sustainable South Bronx, Green Worker Cooperatives, Sustainable Enterprise, and Pratt Center for Community Development;
- Interested Potential Tenants (local and regional business leaders with "green" record);
- Public/Regulatory Agencies: State Department of Environmental Conservation, the Army Corps of Engineers, the State Department of State, the State Historic Preservation Office, the City Landmarks Preservation Commission, City of New York's Office of Long-Term Planning and Sustainability and other appropriate agencies be included in the process so that, if necessary, mitigating measures may be designed and additional permitting processes may be expedited;
- Community Leaders and Community Organizations (who can be a source of political interrupts if they're trying to keep a particular industry away from community);
- Stakeholders include the living inhabitants within the surrounding community, environment, and business community outside of (but local to) the EIP.

The Oak Point EIP in question is a 6 parcel 11.4 acre property that wants to focus primarily on recycling, reuse, and re-manufacturing within its walls. For this example, we're only considering 4 of these parcels to be available (Byron et al 2007).

5.3 - Identification Phase: Defining the Problem

The problem can be defined as the following question: Which firms, upon entering the EIP, can maximize benefits to (1) themselves, (2) other tenants in the park, and (3) the surrounding communities? This problem is heavily dependent on the resource availability of the area, existing industries in the area, and public support or disdain for the candidate tenants. The results from a regional feasibility (as mentioned during Phase 0B) reveal the top regional industrial outputs and inputs (i.e. byproducts, water, electricity, waste heat, specialized services, etc.), and a review of regional education levels will reveal whether the available workforce is ideal for personnel positions required to operate and maintain the EIP.

The proposal to construct an EIP is a consequence of the community's desire for less pressure on the Bronx waste management system (landfills, privatized dump-loader trucks, etc.). An EIP is naturally suited for a region in need of material flow management; however, this all depends on the sort of tenants that the EIP attracts. As will be discussed later, the Analytic Hierarchy Process (AHP) is appropriate for this type of problem because the decision-makers are able to place quantifiable importance on goals for the EIP, no matter how selective. Throughout the proposal, Sustainable South Bronx gave credit to tenant facilities with barge and rail access over dump-loader transport of waste to distant landfills. These preferences were taken into account during the creation of requirements, goals, and criteria for ideal tenants in the South Bronx EIP.

When handling a decision-making problem of this complexity, it is important to define the boundaries of the system under consideration. The EIP in this problem would consist of four tenants (chosen from five potential tenant options), but it is debatable whether to include the Bronx waste and recycling system, or the surrounding Bronx communities that benefit from the reclaimed materials' resultant product or feedstock. In order to capture the full effects of the EIP, I extended the boundaries beyond the gates of the EIP. Many of the tenants within the EIP manufacture products from feedstock supplied to them by the Bronx community (in the form of waste or even valuable recycled construction materials). In return, the EIP tenants process the feedstock and raw recycled material and create their own byproduct or material that has proven utility (i.e. it is marketable to the local and national business community), while diverting these materials from the landfill and helping the Bronx environment. Since the community has such a large influence on the EIP (from materials flowing into it, to ordinances and rules that must be followed) and the EIP has such a large influence on its surrounding community (by creating jobs, resources, a reduction in landfill utilization, etc.), it is important to include the community within this problem's boundary. The proposal cites only two linkages within the EIP's five potential tenants (Byron et al., 2007):

- Captured wood scraps, sawdust and shavings from the Wood Salvage and Re-milling Operation would be sent to the Construction and Demolition Debris Recycling Facility for creation of saleable sand, gravel, and other "stone" products; and
- Scrap shipping pallets used at the Paper Converting Operation would be sent to the Construction and Demolition Debris Recycling Facility.

5.4 - Identification Phase: Determining the Requirements

Determining the system's requirements helps the decision-makers understand what a preferable solution must have (i.e. necessary features) and what it must be capable of doing (i.e. necessary functionality). It is important that these requirements do not discriminate between alternatives. In the case of the EIP design problem, the requirements for potential tenants can be categorized with respect to which aspect of the triple bottom line the requirement intends to represent. As shown in Table 28, there are four requirement types: Community, Environment, Symbiotic Link-ability, and Economy. The community and economy (both local and New York City) requirements are in place to ensure that the potential tenant has the ability to perform in a manner that maximizes the benefit to each of these objectives. The environmental requirements are included to exclude all potential tenants that would be unable to minimize the impact on the environment. And finally, the symbiotic link-ability requirements were generated (1) to ensure that potential tenants are capable of producing waste that can be reused by other tenants (or the community), and (2) to ensure that potential tenant is capable of accepting pre or post-processed waste from other tenants (or surrounding distant/nearby community) and generating marketable products as well.

Community, economic, and environmental requirements should be enough to ensure that the triple bottom line is met. However, none of these three requirement types address the issue of overall project feasibility. The inclusion of the symbiotic link-ability requirements will force the potential tenants to prove that their production system is capable of operating within an EIP setting in a manner that is beneficial to them, the rest of the EIP, and the surrounding community. The development of an EIP would not be worthwhile if most of the tenants could not receive feedstock materials at a discount (from other tenants or the community) or if most the tenants continued sending all their waste to landfills and paying waste transport fees.

Table 28: Requirements for prospective EIP tenants

Requirement Type	Reqt. ID	Requirement for Tenant Explanation
Community (both business and local):	CO1	Tenant must add measurable benefit to community via (any one, or all): • a provided service • recycled byproduct • reception of waste (from community for use in own production methods or beyond) • creation of jobs • training of individuals (i.e. enhancement of human resources)
	CO2	Election of a Tenant for participation in EIP must be approved by all stakeholders (non-profit, environmental and community organizations)
Environment:	EN1	Tenant (or scavenger services that would be included in cluster) must have existing technological capability to reduce use of virgin materials by its facilities
	EN2	Tenant (or scavenger service industries that would be included in cluster) must have existing technological capability to increase the reuse/re-manufacturing of byproducts into useful goods, fuel, or feedstock.
	EN3	To obtain a permit for a presumptively incompatible use (i.e. activity that may be harmful to wetlands), an applicant must overcome the presumption by demonstrating that the project is compatible with the policy of protecting wetlands and is reasonable and necessary, taking into account, among other things, the degree to which the activity is water dependent. So essentially, each tenant must prove their production activities (that include water usage) will not harm wetlands. The applicant must also look at feasible alternatives to the site or approaches that would not affect the wetland, or propose mitigation.
	EN4	With respect to any C&D facility planned for the eco-industrial park, State regulations state that "new solid waste management facilities must not be constructed or operated within the boundary of the regulated wetland." However, a variance of this restriction is possible if the

		tenant proves that the restriction "would impose unreasonable economic, technological or safety burden on the applicant or the public, and that the proposed activity will have no significant adverse impact on public health or the environment" (Byron et al 2007)
Symbiotic Link-ability (Relationship with Neighboring Industries):	SL1	Incoming tenant must either provide or be in demand for byproducts, energy, water, or other services offered by top regional producers or needed by top regional consumers (as determined in Phase 0B)
	SL2	Incoming tenant must have a system for delivering waste heat, material, water, etc. from production facilities to processing/scavenger facility (e.g. material processing facility or grey water treatment facility) and back into market (as feedstock, aggregate, profitable utility, etc.)
	SL3	Incoming tenants must integrate the park-wide conveyor system to enable it to move outgoing products (waste and non-reusable's) directly to barges and rail cars
Economic:	EC1	Industrial clusters must be defined flexibly (so that all sorts of manufacturing and production companies can "fit in" to a cluster and that cluster's associated infrastructure), but with careful attention to most prominent inputs and outputs and the required services associated with these
	EC2	Tenant must participate in symbiotic exchanges that are economic for all parties participating in the exchange • For recipient tenant or community member: the cost of the byproduct or utility service (i.e. electricity or excess heat) that is to be sold to neighboring tenants or communities should not exceed the price the recipient typically pays to contemporary providers of that good or service • For donating tenant: the price charged to recipient tenants or community members by donating clusters should at least cover the cost of reprocessing the waste byproducts prior to resale or reuse for a utility service.

5.5 - Identification Phase: Establishing the Goals

Goals are defined to make clear what the stakeholders and decision-makers "want" or "are hoping" the solution will bring them (Baker et al., 2002). Without a doubt, the triple bottom line should be reflected in these goals (as is in the requirements). According to *Planning for all New Yorkers* (2008), "The goal of an EIP is to improve the economic performance of the participating companies while minimizing their environmental impact." This is a decent goal, but it takes only two types of goals into consideration: economic and environmental. This goal statement neglects to set targets for the community or to consider symbiotic link-ability, both of which would ensure meeting of the triple bottom line (and overall EIP feasibility). Thus, to uphold the principle of the triple bottom line, the missing but necessary goal types are incorporated into the goals (see second and fourth rows of the first column in Table 29). The "Goal Types" are exactly the same as the "Requirement Types" (in the first column of Table 29 and Table 28 respectively); this confirms that the goals and requirements are continuing to strive for achievement of the triple bottom line.

Table 29: Goals for each prospective tenant

Goals Type	Goal ID	Tenant Goal Explanation
Community:	co1	The proposed tenant should be a catalyst for the creation of new opportunities for, as well as improving, the city's recycling programs
	co2	The proposed tenant should alleviate some of the burdens (through reuse of material byproducts or diversion to more distant landfills via barge or rail) which current solid waste management and recycling facilities impose on communities in the Bronx
Environment:	en1	Tenant should have an environmental management system in place, that is capable of integrating with other environmental management systems and facilitating industrial symbiosis to minimize environmental impact
Symbiotic Link-ability (Relationship with Neighboring Industries):	sl1	Tenants should be willing to invest (in conjunction with park management - roughly 50% of construction and installation costs) in infrastructures intended for recycling, reusing, and remanufacturing of byproducts, water/energy, etc.
	sl2	Tenants should be willing to design or integrate new systems capable of taking waste outputs from surrounding tenants and communities and turning them into useful feedstock for their (or others') production processes
Economic:	ec1	With respect to the Solid Waste Management Plan, the new tenant should help the transition from a reliance on private commercial waste trucks (more expensive) to the utilization of barge and rail (less expensive) to reduce stress on the Bronx roads and landfills
	ec2	The proposed tenant should provide high skilled job opportunities for the surrounding community

5.6 - Development Phase: Identifying the Alternatives

For the purposes of this example, the number of parcels available is reduced from six to four (i.e. 7.6 acres in the form of four parcels instead of 11.4 acres in the form of six parcels). The fifth parcel is reserved for the incubator space because it will serve as the "educational-exhibition space" of the EIP. Details on the fifth parcel's purpose are as follows (Byron et al., 2007):

> “. . . A small non-profit facility with educational exhibition space about recycling, re-use, and re-manufacturing and incubator space for craftspeople designing artworks or products made from recycled materials. [Or perhaps it may contain] a small cafe and the possible inclusion of a child-care facility for children of the employees.”

In the field of urban and industrial development, funding can be withdrawn by investors for any reason, and, as a result, property may have to be sold to make up the difference and continue development. In such cases, the number of parcels available would be reduced, much like in the current example. In reality, the six facilities presented below were the final six facilities chosen to make up the Oak Point EIP (Byron et al., 2007). However, there would not be any decision-making needed if six cluster alternatives were presented for six vacant parcels. Therefore, given five alternatives and four open positions, a classic decision-making problem is presented, where the decision-makers must evaluate the five alternative tenants according to a set of criteria (Byron et al., 2007). Each of the four parcels of land available could be used in one of the following ways (Byron et al., 2007):

- A **construction and demolition (C&D) debris recycling facility** that would operate in a fully-enclosed 160,000 square foot building, provide existing C&D transfer stations with financial incentives to close down 2,000 tons-per-day of outdoor operations, replace some 36,500 outgoing truck trips from the Bronx annually (145 daily) with shipments by barge and rail, and create 80 jobs;

- A **plastics product manufacturer** that would produce railroad ties using mixed plastic waste materials from post-industrial and post-consumer sources, provide the city's recycling processors with a convenient market for the 31.5 million pounds of mixed plastics in the city's current recycling stream, enable the recycling program to expand into some of the 245 million more pounds of un-recycled plastics in the city's refuse stream, and create 155 jobs;
- A **paper converting operation** that would convert one-ton "parent rolls" of 100% recycled-content paper into individually-wrapped, consumer-sized rolls and packages of tissues and towel products for sale under its supply contracts with the federal government and major commercial and institutional buyers, and which would create 50 jobs, including 15 for the blind and visually-impaired;
- A **wood salvage and re-milling operation** that would sort heavy and antique timber, beams, joists, shoring lumber and plywood salvaged from demolished buildings and construction sites by dimensions and species, would wholesale about half to lumber mills and timber framing companies, would retail about one-quarter to highway construction, bridge refurbishing, and other contractors, would re-mill the rest into dimensional lumber and blanks for architectural and fine carpentry applications, and would create 20 jobs;
- a **glass powder manufacturing facility** that would process the 77,870 tons of mixed glass cullet and container glass from the city's recycling program into a valuable "green" building material, namely a clean, dry "glass powder"

that can replace up to 40% of the Portland cement used in making concrete masonry blocks and ready-mix concrete, and which would create 30 jobs.

5.7 - Development Phase: Developing the Evaluation Criteria

5.7.1 - Creating the Criteria:

The six criteria were created by acknowledging the goals the alternatives are intended to achieve. The goal is intended to set the target for the alternatives, while the criteria are intended to measure how well the alternatives achieve these targets. It is important to recall that the goals are designed around the triple bottom line, so the purpose of these criteria, is to measure how effectively these potential tenants can aid the EIP in attaining this. Thus, the "Criteria Type" are first defined (exactly the same way as the "Goal Types") to help ensure that the focus of the criteria is on achieving the triple bottom line in a feasible manner. Since the criteria must include all goals, it is important to try to simplify the problem and observe which goals can be combined and later transformed into just one criterion. More importantly, the criteria are derived from the goals by asking what effectiveness measure would best depict how well an alternative is reaching its target. The criteria generated from the goals are listed in Table 30. The "Measure of Effectiveness" column defines equations that are used to calculate how well the alternatives meet the criteria currently (i.e., in 2005).

The measures of effectiveness presented in Table 30 and described here, were created after analyzing the data available from Byron et al., (2007) (the summary of this flow data can be seen in Table 47 through Table 49of the appendix) and were influenced by previous studies in industrial ecology, so it is difficult to cite all but one criterion's measure of effectiveness. The first criterion, Symbiotic Link-ability (or sym1), is intended to measure the difference in connectance values of a fully occupied EIP (including the potential tenant) and a fully occupied EIP that excludes the potential tenant in question (Tiejun 2010). It can be defined as follows:

$$C_e = \frac{2L_e}{S(S-1)} \tag{2}$$

Where:

L_e is the number of byproduct exchange linkages,

S is the number of tenants in the EIP, and

C_e is the observed connectance of the EIP.

From Equation 2, it is evident that as the number of linkages increases, the EIP connectance increases, and the EIP should be appearing more feasible once each tenant is established. It is important to note that the linkages that exist in this example are not just linkages between EIP members, but also between the local and regional communities and distant industries that these tenants are exchanging byproducts with. To help visualize these EIP connectance scenarios, connectance diagrams were constructed to help analyze the connectance criterion for each alternative. An example of one of the connectance diagrams can be seen in Figure 22. It is based on the Construction and Demolition Debris Recycling Facility.

In Figure 22, each potential tenant maintains its abbreviation and is represented by an oblong rectangle. The first box-like rectangle (appearing as "NYC"), represents the New York City (Bronx) community (residential, commercial, public waste and recycling services, etc.) and the second box (appearing as "BC") represents the demanding business community (locally, regionally, and even nationally distributed). The arrows represent the direction of material flow, with the arrow head depicting the materials' eventual destination. Notice the loss in number of linkages when alternative CD is excluded from the EIP. Interestingly enough, the difference in connectance (ΔC_e) is small and negative for most of the alternatives (see sym1 – "Result" column in Table 32) because their absence does not reduce the connectance of the EIP. In these cases, the level of connectance is actually higher when certain tenants are not involved. This is due to the fact that some tenants do not have more than two exchanges occurring between themselves and the rest of the eco-industrial network, making them relatively non-symbiotic. For the other four tenants' connectance diagrams, please refer to the appendix (Figure 25 through Figure 28).

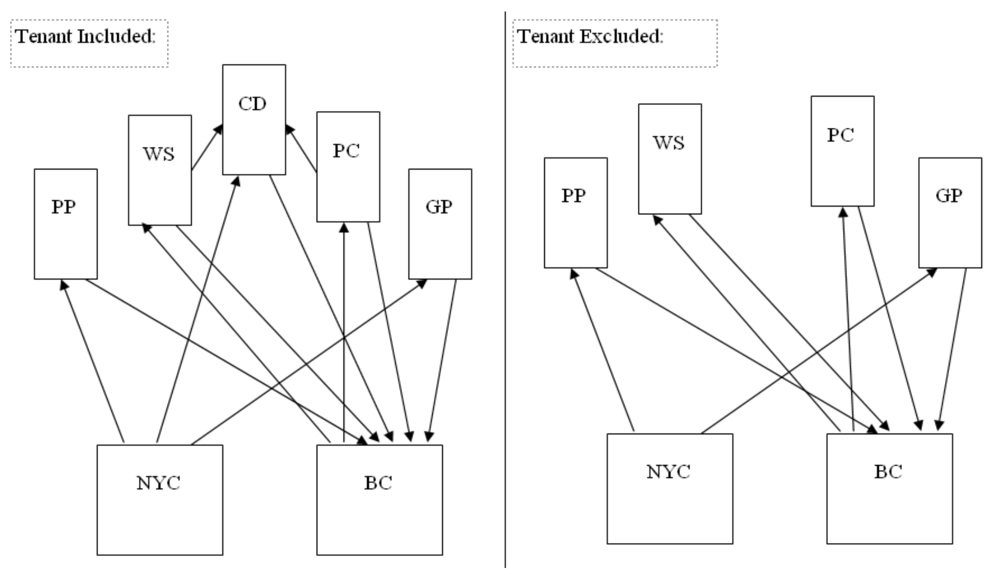


Figure 22: Connectance Diagram for the C & D Recycling Facility

Table 30: Criteria for proposed tenants

Criteria Type	Criteria ID	Tenant Criteria Explanation	Measure of Effectiveness	Units
Community	com1	Does potential tenant have a recycling program with ability to reduce stress on Bronx waste management system?	% of material flows that is recycled = 100*[(Tons of incoming recycled material per year) + (Tons of outgoing recycled material per year)]/[All incoming and outgoing material flow of tenant]	Annual Percentage
Environment	env1	Does tenant have environmental management system capable of integrating with rest of EIP (with knowledge of principles of industrial ecology and how to implement it economically) and capable of continuing to minimize environmental impact (both within the facility and as a component of the EIP and its overall environmental impact minimization efforts)?	Amount of time EMS has been employed at organization	years
Symbiotic Link-ability (Derivative of Economic and Environmental considerations)	sym1	Is potential tenant adding to the overall connectance of the EIP?	Impact on Eco-connectance (C_e) of EIP= (Eco-connectance (C_e) w/ potential tenant) - (C_e of EIP w/ out potential tenant)	linkages/(tenants^2)
	sym2	Is potential tenant capable of producing output for other tenants and communities at a volume/supply rate that is relatively stable and predictable?	Percentage of Output that is Reusable Byproduct = (pounds/gallons/GJ of to-be reprocessed, reusable byproduct produced over the course of a year by potential tenant)/(tons of waste produced + reusable byproduct produced per year)	Annual Percentage
Economic	eco1	Is the potential tenant able to utilize barges and rails (instead of dump loader trucks, flat-bed trucks, roll-off container trucks, etc.) for both reusable and non-reusable waste incoming and outgoing materials/byproducts without interruption to regular operations (not to mention cost effectively)?	Percentage of total (incoming and outgoing) material flows transported by barge and rail = 100*[(tons transportable by barge) + (tons transportable by rail)]/[total tons of product or material coming in and going out]	Annual Percentage
	eco2	Is the potential tenant capable of providing the surrounding communities with a suitable amount of high skill job opportunities?	skilled labor created by facility and supporting services	person(s) employed

5.7.2 – Gathering of Data to Assess Performance of Alternatives versus Criteria:

The two data tables (Table 31 and Table 32) depict the effectiveness of each alternative with respect to each of the six criteria. Each criterion's measure of effectiveness is calculated from the collected tenant data (tenant data is available in Table 47 through Table 49 of the appendix) in accordance with the measure of effectiveness definitions and equations in column four of Table 30).

Table 31: Tenant Alternatives' measures of effectiveness ratings

Tenant ID	TENANT ALTERNATIVES	CRITERIA			
		sym2	eco1	com1	env1
		[Annual %]	[Annual %]	[Annual %]	[years]
CD	Construction and Demolition (C&D) Debris Recycling Facility	93%	45%	96%	5
PP	Plastics Product Manufacturer	99.999%	100%	87%	13
PC	Paper Converting Operation	99.994%	0.006%	99.997%	9
WS	Wood Salvage and Re-milling Operation	99.994%	0.003%	99.997%	11
GP	Glass Powder Manufacturing Facility	70%	100%	85%	7
-	Educational Incubator/Child Care Facility	N/A	N/A	N/A	N/A

Table 32: Continuation of Table 4, two least important criteria

Tenant ID	CRITERIA							
	sym1							eco2
	Tenant Included in EIN			Tenant Excluded from EIN			Result	
	linkages	Participants	[linkages/(tenants^2)]	linkages	Participants	[linkages/(tenants^2)]	[linkages/(tenants^2)]	person(s) employed
	Le	S	Ce	Le	S	Ce	delta-Ce	
CD	12	7	0.571	8	6	0.533	0.038	80
PP	12	7	0.571	10	6	0.667	-0.095	155
PC	12	7	0.571	9	6	0.600	-0.029	50
WS	12	7	0.571	9	6	0.600	-0.029	20
GP	12	7	0.571	10	6	0.667	-0.095	30
-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	~10

5.8 - Development Phase: Selecting a Decision-Making Tool

Given the problem at hand (a small number of alternatives, qualitative goals and quantitative criterion), the most appropriate decision tool to employ is the Analytic Hierarchy Process (AHP). This is useful because it helps the decision-makers avoid having to assign utility functions to each attribute and criteria and, instead, calls for "a series of pair-wise comparison judgments (which are documented and can be reexamined) to express the relative strength or intensity of impact of the elements in the hierarchy" (Baker et al., 2002). Using this method is more efficient than using absolute judgments, where comparing all the alternatives to criterion all at once and trying to select the best one(s) can be quite difficult and far more complex. In addition, a "strength of AHP is its systematic use of the geometric mean to define functional utilities based on simple comparisons and to provide consistent, meaningful results" (Baker et al., 2002).

5.9 - Selection Phase: Evaluating the Alternatives against Criteria

After retrieving all the data on each of the alternatives (as mentioned in Step 5), the AHP begins by making pair-wise comparisons of the six criteria. This is followed by the construction of a comparison matrix (based on the pair-wise comparisons) to yield each criterion's normalized weights. Next, a pair-wise comparison of the alternatives, with respect to the criteria, can be carried out. Fourth, a comparison matrix is once again constructed to evaluate the total normalized score of each alternative. The fifth step entails evaluating the total score of each alternative

(Baker et al., 2002). In essence, the four alternative tenants with the highest total normalized scores would be selected for positions in Oak Point EIP.

5.9.1 – Ranking, Pair-wise Comparison, and Comparison Matrix of Criteria

A ranking of these criteria is presented in Table 33. This ranking portrays the decision-makers' (as well as stakeholders') preferences towards one criterion over another. Preferences were assumed from specific comments regarding needs and wants within Byron et al., (2007).

Table 33: Ranking of criteria prior to pair-wise comparison

Criteria Import. Rank	Criteria ID	Brief Description of Criteria
1	sym2	Ability to create stable amount of byproduct for other tenants and community members
2	eco1	Utilization of barges and rails vs. trucks and other Bronx road users
3	com1	Strength of recycling program
4	env1	Length of time EMS has been in operation
5	sym1	Ability to contribute to symbiotic connectance amongst tenants within EIP
6	eco2	Ability to create highly skilled job opportunities

Table 34: Nine-Point Scale used for pair-wise comparison

1 = Equal importance or preference
3 = Moderate importance or preference of one over another
5 = Strong or essential importance or preference
7 = Very strong or demonstrated importance or preference
9 = Extreme importance or preference

Table 35: Pair-wise Comparison of Criteria

Criterion 1	Criterion 2	Comparison Score
sym2	eco1	3
sym2	com1	3
sym2	env1	5
sym2	sym1	5
sym2	eco2	7
eco1	com1	1
eco1	env1	3
eco1	sym1	5
eco1	eco2	5
com1	env1	1
com1	sym1	3
com1	eco2	5
env1	sym1	1
env1	eco2	3
sym1	eco2	1

A nine-point scale (see Table 34) is used to determine how important one criterion is versus another. The ranking in Table 33 above helps determine which value from the nine-point scale to assign each comparison. Notice that if criterion 1 is more important than criterion 2, the comparison score will be greater than one. If criterion 1 is deemed less important than criterion 2, then the comparison score will be in between zero and one. Table 35 summarizes each of these pair-wise criteria comparisons.

Now that pair-wise criteria comparisons have been established, a matrix can be developed from which we can calculate the normalized weight (i.e. the priority vector) of each criterion. The criteria moving downward (along y-axis) on the table are compared to the criteria running along the top of the table (along the x-axis). Each element in the matrix (see Table 36) is simply a pair-wise comparison of the criteria. The diagonal elements in the matrix are ones, because they are simply a comparison between one criterion, and itself. Above the diagonal, one can notice each element contains the respective pair-wise comparison score, while below the diagonal, the reciprocal of that pair-wise comparison score can be observed. Below the diagonal, the pair-wise comparisons are simply inversed comparisons (e.g. "sym2 compared to com1" has an inverse comparison of "com1 compared to sym2") with respect to those above the diagonal. This explains why cells with the mirrored address of one another have the reciprocal score as one another (e.g. "sym2 compared to com1" scores a 3 while "com1 compared to sym2" scores a 1/3).

Table 36: Normalized matrix generated to determine Criteria's normalized weight of importance

CRITERIA	sym2	eco1	com1	env1	sym1	eco2	Geometric Mean	Normalized Weight	Consist. Ratio
sym2	1.000	3.000	3.000	5.000	5.000	7.000	3.411	0.425	0.041
eco1	0.333	1.000	1.000	3.000	5.000	5.000	1.710	0.213	
com1	0.333	1.000	1.000	1.000	3.000	5.000	1.308	0.163	
env1	0.200	0.333	1.000	1.000	1.000	3.000	0.765	0.095	
sym1	0.200	0.200	0.333	1.000	1.000	1.000	0.487	0.061	
eco2	0.143	0.200	0.200	0.333	1.000	1.000	0.352	0.044	

The geometric mean is calculated for each criterion in the matrix. To determine the normalized weight, the geometric mean of the criterion in question is divided by the sum of the geometric means (e.g. 8.032 in Table 36) of all the criteria. The normalized weight of each criterion will be used later in the evaluation, and they can be seen in Table 36 for reference. Note that the consistency ratio is also preferable; being that it is less than 0.1. Recall, the calculation discussing how to arrive at the consistency index and ratio can be seen toward the end of section 3.4 of this thesis.

5.9.2 – Pair-wise Comparisons, and Comparison Matrices of Alternatives

The process of evaluating the relative importance of each alternative is the same as the process of conducting pair-wise comparisons, and creating the comparison matrix to determine the normalized weight of each criterion. For brevity, the pair-wise comparisons of the alternatives for each criterion, and the normalized matrices were excluded from this body of work. As a summary, the resulting normalized score graphs (showing how each tenant performed with respect to each criteria) can be seen in Figure 29 through Figure 34 of the appendix. As an example, Table 37 shows a pair-wise comparison of the alternatives with respect to the environmental criterion #1 (aka env1). The alternatives' comparison matrix with respect to env1 is generated to determine the normalized score (i.e. relative importance) of each alternative and can be seen in

Table 38. Recall that a discussion explaining how to calculate the consistency index and ratio is presented toward the end of section 3.3 of this thesis.

Table 37: Pair-wise comparison of the alternatives with respect to env1

Pairwise Comparison of Alternatives w/ Respect to Env1		
Alt. 1	**Alt. n**	**Comparison Score**
CD	PP	0.1111
CD	PC	0.3333
CD	WS	0.1667
CD	GP	1
PP	PC	4
PP	WS	1
PP	GP	6
PC	WS	1
PC	GP	1
WS	GP	4

Table 38: Comparison Matrix for alternatives on the attribute env1

ALTS vs. ENV1	CD	PP	PC	WS	GP	Geometric Mean	Normalized Score	Consist. Ratio
CD	1.000	0.111	0.333	0.167	1.000	0.361	0.054	0.0598
PP	9.000	1.000	4.000	1.000	6.000	2.930	0.440	
PC	3.000	0.250	1.000	1.000	1.000	0.944	0.142	
WS	6.000	1.000	1.000	1.000	4.000	1.888	0.284	
GP	1.000	0.167	1.000	0.250	1.000	0.530	0.080	

To be able to ensure that the comparisons between each of the alternatives is valid (with respect to each of the six criteria), the consistency ratio is calculated. The procedure for finding the consistency ratio can be seen in section 3.4. Recall that this ratio must be less than 10%. As an example, criterion env1 has a preferable consistency ratio of 0.0598 because it is less than 0.1 (see Table 38). A complete list of consistency ratios for each of the comparison matrices used to compare alternative Oak Point EIP tenants with respect to the six criteria can be seen in Table 39.

Table 39: Oak Point EIP Evaluation Criteria and the resulting Consistency Ratios after the alternative tenants have been compared.

Oak Point EIP Evaluation Criteria	Consistency Ratio
Sym2	0.0337
Eco1	0.038
Com1	0.0335
Env1	0.0598
Sym1	0.038
Eco2	0.0236

5.9.3 – Determining the Total Normalized Score of Each Alternative

The final step in the AHP is to calculate the total normalized score of each alternative. This calculation involves multiplying the normalized weight of each criterion (second to last column in Table 36) by the alternative's respective normalized score on that criterion (second to last column and the relevant row in

Table 38). The sum of these products is the normalized total score of that alternative (Baker et al., 2002).

$$NTS = \sum_{i=1}^{k}([CW_i]\times[AS_i]) \qquad (3)$$

Where:

NTS is the normalized total score the potential tenant has earned,

CW_i is the normalized weight of the i-th criteria, and

AS_i is the normalized score that the alternative received (with respect to the corresponding i-th criteria)

After the total normalized score (equation 3) for each alternative has been evaluated, the top four scoring tenants can be identified and selected for entry into Oak Point EIP. Figure 23 shows the total scores for our problem's alternatives; the four tenant selections should be: the Construction and Demolition Debris Recycling Facility, the Plastics Products Manufacturer, the Paper Converting Operation, and the Wood Salvage and Re-milling Operation.

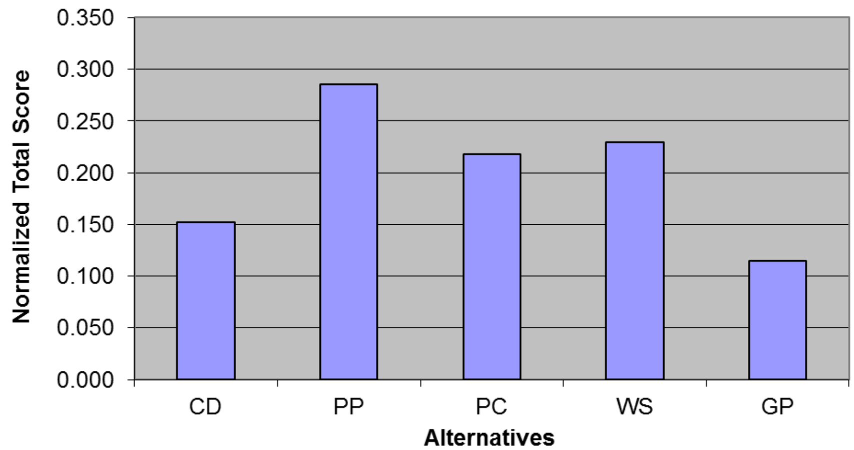


Figure 23: Total Normalized Score of Each Alternative Tenant; the top four scoring alternatives would be heavily considered for entrance into EIP

With respect to the example at hand, the chosen tenants (the Educational Exhibition Space (by default), CD, PP, PC, and WS) generally meet all the goals and requirements; however, there are a few lower than desired performances with respect to criterion Eco1 and Sym1. Two out of the four chosen tenants (PC and WS) would not be able to fully utilize barges and rails (Eco1) because of the nature of both their incoming and outgoing material flows. In addition, three of the four chosen tenants had negative ΔCe. This implies that the connectance of the EIP is not very strong. This could be harmful to long-term feasibility, because if the connectance of the EIP is low, then there is relatively low motivation for the chosen tenants to stay within the EIP if (1) demand for that business' product or service starts to decline (regionally or otherwise), or (2) relied upon incoming resources stop arriving at projected volumes, and operational costs sky rocket. Without increased efforts within the EIP to increase symbiotic link-ability (i.e. promotion of inter-tenant exchange through the Educational Exhibition Space), and a series of upgrades to infrastructure to allow utilization of barges and rails for PC and WS, the Oak Point EIP won't be as successful at achieving the triple bottom line.

Chapter 6: Conclusions and Contributions

Developing EIPs requires making a number of key decisions. For EIP development teams to be successful, these key decisions must be made with confidence and consistency. To ensure confidence and consistency in during the EIP development project, it is crucial that decisions be aligned with organizational goals and that appropriate decision-making methods are used. For an organization to grow and develop sustainably, they must contribute more efforts towards projects other than ones that will progress their financial bottom line. The organizational goals need to be aligned with the other two high-level fundamental objectives (i.e. the societal and environmental bottom-lines) if they seek success for the region (both community and environment) in question and not just the organization itself. If a synthesis can be achieved by industrial park developers and the REIPDP, then an EIP development project should experience a more “well aligned” design and development project that contains objectives capable of aligning with TBL objectives. However, having the right intentions and aligning organizational goals with TBL objectives and mimicking the REIPDP are not enough. In addition, organizations (more importantly EIP development teams) must employ the CDMF and use it to identify the correct decision-making methods per design and development team in question. These decision-making methods are capable of saving development time, preserving needed resources (in the long term), and producing EIPs that can achieve advance triple bottom line objectives and serve the surrounding community more sustainably.

6.1 – Summary of Findings

In summary, society needs to be more conscious of its surrounding and how we impact it. As of late, a push has been made to develop more sustainable systems in areas of industry, building construction, power production, water use, transportation, and other energy and resource intensive, man-made systems. Sustainability should be a worldwide goal, but particularly for any country, state, or region that seeks an equitable future for generations to come. Sustainable development can be achieved through triple bottom line accounting and the employment of industrial ecology and decision based design and development. The triple bottom line accounting method helps developers form goals that will benefit the environment, the community, and the financial well-being of companies involved in the project. Through the application of industrial ecology, developers will produce EIPs that will help a given region achieve a beneficial triple bottom line.

The approach taken to determine how to best improve a region's triple bottom line via industrial ecology and EIP development began with the study of literature discussing sustainable development, industrial ecology, implementation of eco-industrial parks, and decision-based design methods and principles. These efforts led to the creation of the GEIPDP. From here, 21 EIP development projects were analyzed and compared to the GEIPDP for correlation. This analysis revealed the characteristics of the 21 studied EIP development processes. Based on the observations made, the 21 EIP processes could be categorized by stimuli, solution, and problem type. Upon completion of this analysis, it became clear that most of these decision processes belong to the same three categories (i.e. opportunity-type problems that require dynamic design decision processes and yield modified solutions) and, thus, can be approached, from a decision-making process standpoint, in the same manner. After concluding that revisions were needed, the REIPDP was constructed, and the correlation between it and the studied EIP development projects improved. Once this was done, one more evaluation was needed to determine whether the REIPDP was, in fact, the most aligned with the TBL (with respect to the other 21 EIP development processes studied). The evaluation carried out late in Chapter 3 validates that the REIPDP is well aligned with the TBL objectives. This is evident from the fact that it satisfies both evaluation criteria; a result that only two other EIP development processes studied were able to attain. Once the REIPDP was validated, its key decisions were analyzed using the CDMF to identify appropriate decision-making methods. One step in the development of the Oak Point EIP was used as an example of how to approach an EIP development decision. This example illustrated several concepts that EIP development teams can utilize during the decision of selecting tenants from a pool of alternative businesses and/or service providers.

6.2 - Limitations

6.2.1 – Training in Risk Analysis

The first shortcoming to this thesis involves the lack of an EIP design and development process risk assessment. The area of risk was avoided in this thesis because it is beyond the scope of my expertise. Given more time, participation in graduate courses dealing with risk analysis would have contributed greatly to my understanding of how to conduct a risk assessment properly. This knowledge would have been applied to the example considering the EIP tenant selection at Oak Point EIP. The consideration of risk is often utilized by investors, project initiators, and the development teams to determine the probability of a hazardous event occurring and its magnitude (i.e., resulting losses observed by decision-makers and stakeholders if a given hazard, or set of hazards, occurs). Risk assessments are typically carried out before the initiation of large scale projects of $1 billion or more because there is a lot of risk in terms of finance, safety, and social and environmental impacts (Flyvbjerg et al., 2003). The design and development of EIPs should include a risk assessment and a risk mitigation plan within the proposal and action plan respectively.

6.2.2 – Lack of Return on Assets Calculation

This body of work neglects two very important calculations that would be considered by important to potential tenants and potential investors. The return on assets calculation would help EIP developers gauge how strong a company within a particular industry is by considering the ratio between its net income and its average total assets. This calculation is not useful when comparing companies across different industries, however, because of factors of scale and operational capital requirements (Cram, 2003). The return on assets calculation could have been included in the Oak Point EIP example as a criterion to define an economically stable company; however, not enough financial data was supplied for calculation of the alternative tenants' return on assets value. More generally, the return on assets calculation could have been included in the objective function as a variable indicating the increase (or decrease) in economic well-being of a tenant that entered an EIP.

With relevant financial data describing tenants' revenue stream and assets, a return on assets calculation could be evaluated to prove how financially beneficial (or detrimental) co-location onto an EIP site can be.

6.2.3 – Proprietary Information Dissemination

Trust between companies competing in similar and dissimilar market is not often present in the current world of business. However, trust filled relationships between managers are a requirement before industrial symbiosis projects (like the ones at Kalundborg) can commence. Byproduct exchange information typically falls under the umbrella of proprietary information that companies are reluctant to share with any other organization. The sensitivity of this sort of information makes it difficult to uncover by EIP development teams and management boards searching for byproduct exchange opportunities. Research on byproduct related proprietary information creates a shortcoming to this study because industry wide generalizations about material flow streams, energy requirements, and water usage and quality (as shown in Table 40 in the Appendix) can only define byproduct exchanges on a broad sense. To be able to ensure that an EIP will be able to accomplish mass, energy, and water balances, the operational specifications of each tenant must be made available to the EIP development teams and management boards. Since I was unable to work closely with a functioning EIP, data of this sort could not be recovered and augmented (to protect the privacy of the companies relinquishing this data) for a more in-depth analysis of an EIP's byproduct exchange network. With more transparency from companies, coupled with a system for maintaining company anonymity, more research could have been conducted to mathematically demonstrate the benefits that an EIP can have on its surrounding region.

6.3 – Contributions

The contributions of this research are primarily three fold. First of all, this thesis presents an analysis of the EIP development process that is used to identify the key decisions that need to be made. The analysis of the 21 studied EIP development processes demonstrates one way to identify key decisions and also demonstrates how to find alignment between the objectives of these decisions, and the TBL's objectives. The creation of the four attributes used to determine how well aligned an EIP development process is may be useful to EIP development teams who seek to advance as many TBL objectives as possible.

On a more general note, this thesis contributes to the field of industrial ecology and decision based design by providing decision makers within the area of eco-industrial development with suggestions for appropriate decision-making methods. The revised EIP development process presents real EIP development teams with a summary of the key decisions and actions EIP development teams typically address. Before this research was conducted, a wide variety of different EIP development processes could be studied, but the EIP development team would have to keep in mind that each process is tailored to meet a specific region's requirements and goals. The revised EIP development process, however, maintains flexibility and encompasses actions and decisions that apply to all EIP development projects, regardless of the region they are applied to. Before conducting this research, I knew very little about the area of industrial park development and economic revitalization;

two areas that rarely come in contact with mechanical engineering design. Now that research has concluded, I feel that this area deserves more attention from systems engineers and industrial engineers alike. More innovative manufacturing and production systems need to be created to align industrial practices with those emphasized by industrial ecology.

The last contribution this thesis makes is to the field of decision based design. The ideas of decision-based design were developed in the quest to understand and improve engineering design and product development. This thesis shows that other design processes in other domains can also benefit from carefully considering the key decisions that need to be made. Different EIP development processes will vary in many ways, but the key decisions encompassed in the REIPDP should be included in any EIP project that hopes to make a positive impact, because the identified key decisions are the critical backbone of any EIP development process. This research provides the first evidence that decision-based design is useful outside the domains of engineering design and product development by suggesting decision-based design methodologies that can be applied to the realm of eco-industrial development.

6.4 – Future Work

Given more time, one possible direction includes a more detailed analysis of a particular EIP development process. This detailed analysis would begin with the identification of key decisions and being sure to understand the objectives and constraints of these decisions. With more detailed information about the objectives and constraints of these key decisions, evaluating the alignment of organizations' objectives with that of the TBL objectives would be more conclusive. From here, it would be more possible to analyze the actual decision-making methods used and a study could be conducted to determine whether changing the decision-making method could lead to a better outcome.

In addition to decision-based design of EIPs, more research could be geared towards other development processes that impact the community and environment as well. For example, urban development that includes commercial and residential units (like the proposed East Campus Initiative at our very own University of Maryland), manufacturing facilities, or other multi-organization development projects could certainly benefit from new development processes that utilize decision-based design methods and aim to improve regional triple bottom lines.

6.4.1 –Government Agency Involvement

An avenue for future work in industrial ecology and applying it to regions across the United States exists if the relevant government agencies (e.g., environmental protection agencies, economic development agencies, or urban planning agencies) get involved. Grants can be awarded by these agencies to support feasibility studies that unveil a region's potential (or lack of potential) for the design and development of an EIP. These feasibility studies can be conducted by industrial ecology experts from sustainable development consulting firms, universities, and other organizations qualified for this duty. A great supportive measure that government agencies can employ is the creation of a virtual byproduct exchange network (e.g., via the internet) that will allow companies to search for, and provide information about, byproducts that they (and other enterprises) may find useful. The development of virtual byproduct exchange networks (like the one at Devens EIP) would be a great benefit to the advancement of industrially ecological practice.

If possible, future government sponsored research would focus on the creation of a nationwide byproduct database that automatically searches for, matches and notifies participating companies of potential byproduct exchanges. Companies would be able remain anonymous while conducting a search for byproducts from mutually anonymous companies. Upon permission from both companies, a third party (ideally, non-profit industrial ecology experts) could receive hard data about each company's material, water, and energy specifications (as a function of their operational and production processes) and conduct an analysis determining whether a byproduct exchange between the two companies is feasible or not. These potential byproduct exchanges would be determined with respect to company geography, operational and production process information (detailing required inputs and resultant outputs), and additional criteria that have not been determined yet.

6.4.2 – More Communication of Experiences between Past and Present EIP Development Teams

Another avenue for future work entails greater communication with past and existing EIP development teams. If there were a better accounting of which development activities tend to fail, which tend to succeed, and this information is disseminated to development teams nationwide, then the EIP design and development process would be better understood and, as a result, would improve. Part of being successful requires the ability to learn from the mistakes and successes of those that came before us, and applying this wisdom towards something that will benefit us, our societies, and the world we live in. For an EIP development team to be successful, it must take advantage of the documented lessons learned and use them to aid in high-quality decision-making.

Appendices

(Begins on next page)

Table 40: Common Industry Inputs and Outputs

INDUSTRY (SUB-SECTOR) CLUSTER	REQUIRED INPUTS		BY-PRODUCT OUTPUTS				NOTES
	Composition	To Manufacture	By-Product	Beneficial Uses	Potential Cluster Industry/Company Link	ANNUAL OUT. (1999 U.S.)	
Cement	calcium, silicon, aluminum, and iron (i.e. mixture of limestone, clay, sand, water and iron ore)	fly ash, foundry sand, baghouse dust, refractories, causticizing residue, scrap tires, and mine tailings	Cement Kiln Dust (CKD)	Land application as agricultural soil amendment	Agricultural Ind.	14.2M tons (4.3M usable tons)	Limited number of by-products that result; Primarily a recipient industry
				Mineral filler in asphalt paving	Asphalt Co. (Bldg. Mat'l)		
				Replacement for Portland cement in concrete block manufacturing	Cement Co. (Bldg. Mat'l)		
				Replacement for Portland cement in redi-mix concrete	Cement Co. (Bldg. Mat'l)		
				Hydraulic barrier in a landfill liner/cover	Cement Co. (Bldg. Mat'l)		
				Flowable fill or controlled low-strength material (CLSM)	Cement Co. (Bldg. Mat'l)		
				Sorbent to remove sulfur dioxide from cement kiln flue gas	Coal Power Ind.		
				Waste solidification/Soil stabilization	Fertilizer Co. (Agricultural Ind.)		
				Mine reclamation	Mining Ind.		
Foundry	ferrous (grey iron, ductile iron, malleable iron, and steel) and non-ferrous (aluminum, brass, bronze, zinc, magnesium, titanium, nickel, cobalt, and tin) metal alloys	ferrous (grey iron, ductile iron, malleable iron, and steel) and non-ferrous (aluminum, brass, bronze, zinc, magnesium, titanium, nickel, cobalt, and tin) metal alloys put through high heat metal forming proceses	Foundry Sand (Primarily) (Green (mostly) and Chemically Bonded Sand)	Soil blending/Manufactured topsoil/Potting soil/Compost	Agricultural Ind.	$27B Worth in castings; 15-20M tons of scrap metal that is recycled	Primarily an provider industry for Bldg. Mat'l Industry
				Partial replacement for Fine aggregate in asphalt paving	Asphalt Co. (Bldg. Mat'l)		
				Rock wool - building material insulation, and are similar to fiber glass	Building Materials Ind.		
				Road base/subbase	Building Materials Ind.		
				Structural fill (compacted in 6" to 12" inch lifts)	Building Materials Ind.		
				Partial replacement of fine aggregate material for (Portland) cement concrete manufacturing	Cement Co. (Bldg. Mat'l)		
				Aggregate for flowable fill (CLSM - consists of sand, water, cement, and sometimes fly ash)	Cement Co. (Bldg. Mat'l)		
				Hydraulic barrier in landfill final cover	Landfill Ind.		
				Alternative daily cover - 6 inches of daily soil cover required by states for active faces of a landfill	Landfill Ind.		
			Foundry Slag (Primarily)	Coarse aggregate for asphalt (pass ¾ inch sieve)	Asphalt Co. (Bldg. Mat'l)		
				Coarse aggregate for highway subbase	Building Materials Ind.		
				Coarse aggregate for concrete	Cement Co. (Bldg. Mat'l)		
				Raw material for cement manufacturing (e.g. Portland cement)	Cement Co. (Bldg. Mat'l)		
			Baghouse Dust	Raw material for cement manufacturing (e.g. silica sub in Portland cement)	Cement Co. (Bldg. Mat'l)		
				Filler for plastic extrusion (increases weight of extruded plastic parts)	Plastic Mfg. Co.		
			Furnace and Ladle Refractory	Raw material for cement manufacturing (silica and alumina subs in Portland cement)	Cement Co. (Bldg. Mat'l)		
Pulp and Paper	wood fiber or secondary fiber (recycled paper)	pulp from wood and from recycled paper as the sources of fiber	Residuals (wood fibers, minerals, and microbial biomass) from Wastewater Treatment Plant (WTP)	Soil amendment	Agricultural Ind.	$79Bin pulp and paper prod.; 3/5.8M tons unused WTP residuals	On-site treatment often consists of clarification (primary) and biological (secondary) treatment to remove suspended solids and soluble organic materials
				Compost (horticultural, agricultural, land reclamation, landscaping, and individual consumer application to sustain soil nitrogen reserves and improve soil structure)	Agricultural Ind.		
				Absorbent/Animal bedding	Agricultural Ind.		
				Admixture in Portland cement concrete (source of wood fiber (increases durability, pumpability, and shrink related cracking in concrete))	Cement Co. (Bldg. Mat'l)		
				Raw material in cement manufacturing (feedstock)	Cement Co. (Bldg. Mat'l)		
				Structural and nonstructural solid panel and profile products (i.e. building board) from extrusion	Cement Co. (Bldg. Mat'l)		
				Lightweight/Glass aggregate	Glass Making Ind.		
				Alternative daily cover	Landfill Ind.		
				Hydraulic barrier in landfill cover systems (vs. clay)	Landfill Ind.		
			Power Boiler Ash (coal-fired but mostly wood-fired)	Soil amendment (fertilizer and substitute for agricultural lime)	Agricultural Ind.	Total: 2.8M tons Wood-fired Ash: 2.0M tons to landfills Coal-fired Ash: 0.42M tons	Percentages (of 2.8M tons): Coal-Fired Ash = 15% Wood-Fired Ash = 22% Mixed Fuel Source Boiler Ash = 63%
				Compost (substitute for bark and other materials)	Agricultural Ind.		
				Soil waste stabilization	Agricultural Ind.		
			Causticizing Mat'ls (lime mud, lime slaker grits, and green liquor dregs)	Soil amendment (lime mud replaces agricultural limestone)	Agricultural Ind.	1.7M tons (1.4M tons goes to landfills)	Reuse should take advantage of the calcium content and/or alkalinity of these materials
				Soil stabilization (lime slaker grits)	Agricultural Ind.		
				Raw material in cement manufacturing (feedstock - Ca, Al, and Fe)	Cement Co. (Bldg. Mat'l)		
				Alternative daily cover	Landfill Ind.		
Utility Industry (Coal Comb. Prod.)	Coal Ash: a variety of noncombustible minerals, which consist primarily of silica, alumina, and iron, with smaller percentages of calcium, magnesium, sulfates, and other compounds	Coal and coal-fired electric generating stations	Fly Ash	Waste solidification/Soil stabilization	Agricultural Ind.	118M tons in 2001 (81M tons going to landfills): - Fly Ash = 68 M tons (44M tons landfilled) - Bottom Slag = 2.5M tons (0.7M tons landfilled) - Bottom Ash = 18.8M tons (13M tons landfilled) - Flue Gas Desulferization = 28M tons (21M tons landfilled)	Two classes of Fly Ash: Class C - derived from subbituminous and lignite coal; is self-cementing (replaces Portland cement content) and a liming agent (20% lime) Class F - from bituminous and anthracite coal; for structural fills
				Soil amendment	Agricultural Ind.		
				Mineral filler in asphalt paving	Asphalt Co. (Bldg. Mat'l)		
				Grout	Building Materials Ind.		
				Structural fill (to construct fills and embankments)	Building Materials Ind.		
				Flowable fill is a mixture of coal fly ash, water, sand, and Portland cement that flows like a liquid, sets up as a solid, and is self-leveling	Cement Co. (Bldg. Mat'l)		
				Mineral admixture in Portland cement concrete	Cement Co. (Bldg. Mat'l)		
			Bottom Ash/Boiler Slag	Soil stabilization/Waste solidification	Agricultural Ind.		
				Snow and ice control (anti-skid material)	Anti/De-Icing Material Co.		
				Fine aggregate in asphalt paving	Asphalt Co. (Bldg. Mat'l)		
				Granular base (pavement construction)	Building Materials Ind.		
				Structural fill (after careful evaluation)	Building Materials Ind.		
				Roofing shingle granules	Building Materials Ind.		
			Flue Gas Desulfurization (FGD) Material	Soil stabilization/Waste solidification	Agricultural Ind.		
				fly ash	Agricultural Ind.		
				Wallboard (used to replace gypsum)	Building Materials Ind.		
				Structural fill	Building Materials Ind.		
				Admixture in Portland cement concrete (retard the setting of concrete)	Cement Co. (Bldg. Mat'l)		
				Mine reclamation	Mining Ind.		

Figure 24: SCIP site plan (Lowe et al., 2005)

Table 41: Main Features of US EIPs from Interview Survey (Gibbs and Deutz, 2005)

Park	Location	Status	Funding	Developer	Objectives	'Greenness'
Devens Planned Community, MA	Former army base, rural area	Opened 1996	Public—incl. Federal	Public agency	Balancing economic development, environmental performance and social values	Eco Star Program, green building incentives
Phillips Eco Enterprise Center, MN	Urban area, deprived neighbourhood	Opened 1999	Public (state) and private	Community non-profit	Living wage jobs, clean industries	Architecture, some 'green' tenants
Port of Cape Charles Sustainable Technology Park, VA	Rural, remote location in economic decline	Opened 2000	Public (county)	Public agency	Creation of living wage jobs	Architecture, covenants, points system
Gulf Coast By Product Synergy Project, Freeport, TX	Large petrochemicals complex	Phase 1 2003 (internal to Dow Chemicals); Phase 2 2004 (with 10–15 companies)	Private and public (Federal)	Private companies /US BCSD	Reduced wastes and costs	Waste treatment facility, utilities, by-product synergy
Londonderry Eco-industrial Park, NH	Small community, adjacent to new airport and freeway to Boston	Under construction	Private	Private sector	Strengthen local economy, reduce environmental impacts	Covenants, architecture, gas fired power plant as anchor tenant, water treatment
Redhills Ecoplex, MS	Rural location, next to lignite mine and power plant, high job losses	Under construction	Public	Public agency	Job creation	Recruiting for loop closing, power plant as anchor tenant
Dallas Eco-industrial Park, TX	Run down neighbourhood in South Dallas	Under construction	Public (Federal)	Local authority	Job creation, improving neighbourhood	Environmental education
Ecolibrium, Computer and Electronic Disposition, Austin, TX	Outskirts of Austin on major landfill site	Planned	Public (Federal)	Public sector consortium	Reduced waste to landfill, job creation	Recycling computers and electronic equipment
Front Royal, Eco Office Park, VA	Washington DC commuter belt	Planned	Public (Federal)	Public agency	Jobs for residents, reduce commuting outside town	Architecture, networking
Bassett Creek, MN	North of downtown Minneapolis	Proposed	Public (city)	Consultants/local authority	Creating labour intensive businesses	Networking—energy, materials, personnel

Table 42: Categorizing of an EIP Development Process with respect to the Strategic Decision Process (EIP development process provided by (Nolan, 2004) and the Strategic Decision Process provided by (Mintzberg, 1976))

I. The Planning Phase:	Recognition	Diagnosis	Search	Design	Eval. Choice	Authoriz.
1.1 Involve community and community leaders	1					
1.2 Conduct background research (traditional baseline analysis + EID specific baseline analysis + Economic and environmental evaluation)		1				
1.3 Conduct technology and market analysis		1				
1.4 Create alternative development scenarios *(two Phases below)*		1	1			
1.5 Evaluate and prioritize implementation strategies		1				
II. Design Phase:						
2.1 Prepare conceptual EID site or cluster scenarios				1		
2.2 Develop site master plans				1		
2.3 Develop schematic design and engineering			1	1		
2.4 Develop model codes, covenants, and restrictions and establish oversight authority			1	1		
2.5 Develop Umbrella permitting model				1		
III. EID Construction Phase:						
3.1 General construction schedule				1		
3.2 Regulatory Approvals					1	1
3.3 Infrastructure and site preparations						

Table 43: Fundamental & Means Objective Network for the REIPDP – Phases 0A and 0B

Phase/Step Exercised	Objective(s) of Decision (What)	Means-Objectives			Low-Level Fundamental Objectives Advanced		High-Level Fundamental Objective Advanced
Phase 0A: Identify, involve, and establish primary actors internally (EIP development team) and externally (within local business (resource exchange network, industrial associations, etc.), regulatory agencies, and community) via regionwide social function (conference, meeting, symposium, etc.)	Identify role players; change agent can begin to "spread influence" and garner support from stakeholders. Funding for initial/pre-development activity (business surveys and conferences, community meetings, drafting of prelim. plans or guidelines, etc.) is typically provided by these decision makers	Maximize opportunities for beneficial and sustainable symbiotic exchanges between considered (or already recruited) businesses	Maximize efforts towards resource reuse, recycling, and recovery	Minimize use of virgin materials and potable water	Maximize material-usage efficiency		Maximize Environ. Bottom Line
					Maximize water-usage efficiency		Maximize Environ. Bottom Line
					Maximize preservation of natural habitats		Maximize Environ. Bottom Line
			Minimize supply and disposal costs of resources needed by tenants		Maximize economies of scope and scale for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
					Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Maintain high percentage of employees and management hired from surrounding communities			Maximize community's opportunities for human capital improvement		Maximize Societal Bottom Line
					Maximize employee and customer satisfaction		Maximize Societal Bottom Line
Phase 0B: Establish goal, scope, implementation strategy, principles, guidelines for potential tenants and proposal for development of region's "ideal" EIP. ALL stakeholders and decision makers should be in consensus by the end of this phase (Also called Terms of Reference)	Define scope of the EIP project - all stakeholders and decision makers will be offering ideas and concepts and consensus is eventually reached (guidelines and principles are developed). Feasibility studies are began to determine if project can achieve environmental, economic, and social equity. A proposal is also drafted to determine sources of funding and to advertise the EIP to prospective tenants	Minimize emissions of hazardous and solid wastes	Maximize efforts towards resource reuse, recycling, and recovery	Minimize use of virgin materials and potable water	Maximize material-usage efficiency		Maximize Environ. Bottom Line
		Minimize global warming potential (CO2)			Maximize water-usage efficiency		Maximize Environ. Bottom Line
		Minimize ozone-depleting potential (CFC-11 equivalent)					
		Minimize harmful emissions into water			Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Promote "green" building standards (LEED and Green Built)			Maximize energy-usage efficiency		Maximize Environ. Bottom Line
					Maximize material-usage efficiency		Maximize Environ. Bottom Line
		Minimize use of fossil fuels and other non-renewable energy	Maximize use of renewable energy sources		Maximize energy-usage efficiency		Maximize Environ. Bottom Line
		Ensure community leaders' concerns and input is listened to and incorporated into EIP development project			Maximize employee and customer satisfaction		Maximize Societal Bottom Line
		Maximize effectiveness of programs for skills management, lifelong learning, career ending management, and job-specific training			Maximize community's opportunities for human capital improvement		Maximize Societal Bottom Line
		Ensure region's resources are utilized by local businesses efficiently and in industrial zones that are optimally designated and do not negatively impact nearby residential zones			Maximize employee and customer satisfaction		Maximize Societal Bottom Line
					Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Maximize number of new jobs created by EIP tenants			Minimize community's unemployment rate	Increase regional government's tax revenues	Maximize Economic Bottom Line
						Maximize Gross Regional Domestic Product (GRDP)	Maximize Economic Bottom Line
		Minimize supply and disposal costs of resources needed by tenants			Maximize economies of scope and scale for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
					Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Minimize costs of utilities for tenants and community			Minimize operational and EIP entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line

Table 44: Fundamental & Means Objective Network for REIPDP - Phases 1 -3

Phase/Step Exercised	Objective(s) of Decision (What)	Means-Objectives		Low-Level Fundamental Objectives Advanced		High-Level Fundamental Objective Advanced
Phase 1: Develop Action Plan	Create an action plan that acknowledges challenges (use guidelines and principles to address), notes benefits, creates initial estimates (for land required and cost of infrastructure, utilities, etc.), and mentions possible sources of funding and why those entities would be interested (e.g. ROI, regional economic revitalization, job creation, environmental waste reduction, etc.). Also highlights roles and responsibilities of decision makers in the project	*** This part of the phase is an action (not a Decision) that does not contribute to the region's TBL but still needs to be done to further development ***		N/A		N/A
Phase 2: Brownfield/Greenfield site search and evaluation (More Detailed Feasibility Analysis of Region with respect to its Inhabitants and Resources). Followed up with Acquisition, and Preparation (includes site remediation, infrastructure and public services installation, and public facility construction) after authorization	Determine where in region EIP can feasibly operate and maintain sustainable growth (i.e. Answer where the EIP will be able to achieve the triple bottom line?).	Ensure region's resources are utilized by local businesses efficiently and in industrial zones that are optimally designated and do not negatively impact nearby residential zones		Maximize employee and customer satisfaction		Maximize Societal Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Minimize rates of occupational injury, diseases and fatality to employees and subcontractors		Maximize community's health and wellness		Maximize Societal Bottom Line
		Minimize number of fines and non-monetary sanctions imposed on EIP tenants for non-compliance with laws and regulations		Maximize community's level of safety and security		Maximize Societal Bottom Line
				Maximize community's health and wellness		Maximize Societal Bottom Line
		Minimize costs of utilities for tenants and community		Minimize operational and EIP entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
Phase 3: Identify ideal industrial-cluster linkages with respect to chosen location (also consider required supporting non-industrial inhabitants) and projected anchor(s).	Identify which industrial clusters can be colocated in order to maximize economies of scale (i.e. profitable symbiotic linkages) and byproduct, energy, and/or water exchange, while minimizing waste creation. From this, a site-wide information management service could be created (e.g. EcoStar at Devens)	Recruit businesses that can "close" the EIP's energy, mat'l, and water loops	Maximize number of new jobs created by EIP tenants	Minimize community's unemployment rate	Increase regional government's tax revenues	Maximize Economic Bottom Line
					Maximize Gross Regional Domestic Product (GRDP)	Maximize Economic Bottom Line
			→	Maximize growth of new businesses within community	Increase regional government's tax revenues	Maximize Economic Bottom Line
					Maximize Gross Regional Domestic Product (GRDP)	Maximize Economic Bottom Line
			Minimize supply and disposal costs of resources needed by tenants	Maximize economies of scope and scale for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
				Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Minimize costs (and time spent) for regulatory compliance (Umbrella permitting)		Minimize operational and EIP entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Maximize efforts towards resource reuse, recycling, and recovery	Minimize use of virgin materials and potable water	Maximize material-usage efficiency		Maximize Environ. Bottom Line
				Maximize water-usage efficiency		Maximize Environ. Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Minimize use of fossil fuels and other non-renewable energy	Maximize use of renewable energy sources	Maximize energy-usage efficiency		Maximize Environ. Bottom Line

Table 45: Fundamental & Means Objective Network for the REIPDP – Phases 4 & 5

Phase/Step Exercised	Objective(s) of Decision (What)	Means-Objectives		Low-Level Fundamental Objectives Advanced		High-Level Fundamental Objective Advanced
Phase 4: Identify, Evaluate and Secure inhabitant businesses for each industrial (and non-industrial support service) cluster	Screen and recruit businesses that can, upon entering, maximize benefit to (1) themselves, (2) others in the park, and (3) the community	Ensure region's resources are utilized by local businesses efficiently and in industrial zones that are optimally designated and do not negatively impact nearby residential zones		Maximize employee and customer satisfaction		Maximize Societal Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Recruit businesses that can "close" the EIP's energy, mat'l, and water loops	Maximize number of new jobs created by EIP tenants	Minimize community's unemployment rate	Increase regional government's tax revenues	Maximize Economic Bottom Line
					Maximize Gross Regional Domestic Product (GRDP)	Maximize Economic Bottom Line
			→	Maximize growth of new businesses within community	Increase regional government's tax revenues	Maximize Economic Bottom Line
					Maximize Gross Regional Domestic Product (GRDP)	Maximize Economic Bottom Line
			Minimize supply and disposal costs of resources needed by tenants	Maximize economies of scope and scale for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
				Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Maximize efforts towards resource reuse, recycling, and recovery	Minimize use of virgin materials and potable water	Maximize material-usage efficiency		Maximize Environ. Bottom Line
				Maximize water-usage efficiency		Maximize Environ. Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
Phase 5: Determine Optimal Layout - EIP Prototype Scenario Exploration	Determine layout that complements byproduct and energy exchange projects and maximizes the (1) economic, (2) environmental, and (3) sociological benefits created by the EIP	Ensure region's resources are utilized by local businesses efficiently and in industrial zones that are optimally designated and do not negatively impact nearby residential zones		Maximize employee and customer satisfaction		Maximize Societal Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Maximize efforts towards resource reuse, recycling, and recovery	Minimize use of virgin materials and potable water	Maximize material-usage efficiency		Maximize Environ. Bottom Line
				Maximize water-usage efficiency		Maximize Environ. Bottom Line
				Maximize preservation of natural habitats		Maximize Environ. Bottom Line
		Minimize use of fossil fuels and other non-renewable energy	Maximize use of renewable energy sources	Maximize energy-usage efficiency		Maximize Environ. Bottom Line
		Minimize supply and disposal costs of resources needed by tenants		Maximize economies of scope and scale for EIP tenants	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
				Minimize operational and EIP-entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line
		Minimize costs of utilities for tenants and community		Minimize operational and EIP entry costs to each tenant	Maximize EIP companies' profit margin	Maximize Economic Bottom Line

Table 46: Fundamental & Means Objective Network for the REIPDP – Phases 6 and Omega

<table>
<tr><th>Phase/Step Exercised</th><th>Objective(s) of Decision (What)</th><th colspan="2">Means-Objectives</th><th>Low-Level Fundamental Objectives Advanced</th><th>High-Level Fundamental Objective Advanced</th></tr>
<tr><td rowspan="6">Phase 6: Organize and Determine regulatory and managerial responsibilities to be held by EIP management and regulatory agents</td><td rowspan="6">Determine structure (abilities and limitations) and personnel of EIP mgmt team as well as the regulatory liasons affiliated with the EIP. This will ensure that the critical stakeholders and decision makers during the development process will remain in positions of influence</td><td colspan="2">Ensure community leaders' concerns and input is listened to and incorporated into EIP development project</td><td>Maximize employee and customer satisfaction</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td colspan="2" rowspan="2">Maintain high percentage of employees and management hired from surrounding communities</td><td>Maximize community's opportunities for human capital improvement</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td>Maximize employee and customer satisfaction</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td colspan="2">Minimize rates of occupational injury, diseases and fatality to employees and subcontractors</td><td>Maximize community's health and wellness</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td colspan="2" rowspan="2">Minimize number of fines and non-monetary sanctions imposed on EIP tenants for non-compliance with laws and regulations</td><td>Maximize community's level of safety and security</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td>Maximize community's health and wellness</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td rowspan="3">Phase Omega: Implementation and Construction</td><td rowspan="3">Full development of EIP: construction of green design initiatives, finalization and initiation of industrial symbioses projects, and community improvement/education initiatives are begun here</td><td rowspan="2">Maximize number of community members who are educated in IE principles and capable of being employed at one of the EIP tenant facilities</td><td rowspan="2">Maintain high percentage of employees and management hired from surrounding communities</td><td>Maximize community's opportunities for human capital improvement</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td>Maximize employee and customer satisfaction</td><td>Maximize Societal Bottom Line</td></tr>
<tr><td colspan="2">Maximize effectiveness of programs for skills management, lifelong learning, career ending management, and job-specific training</td><td>Maximize community's opportunities for human capital improvement</td><td>Maximize Societal Bottom Line</td></tr>
</table>

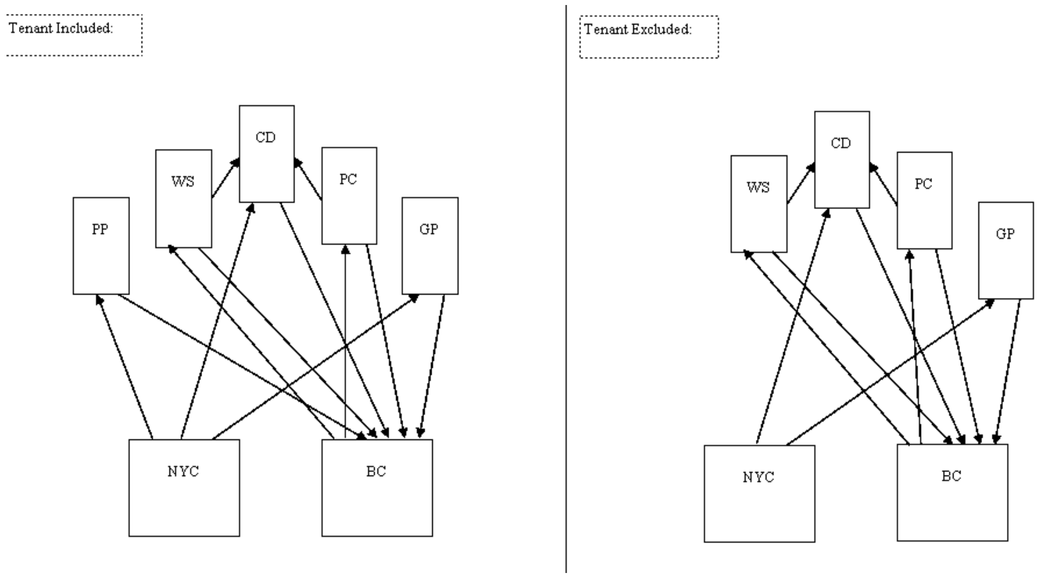


Figure 25: Connectance Diagram for the Plastic Product Manufacturer (PP)

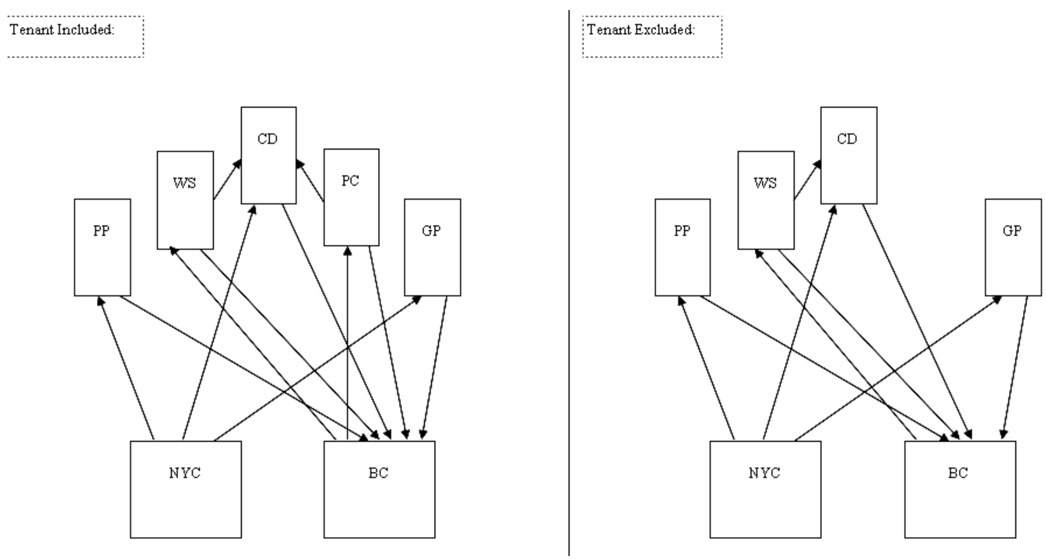


Figure 26: Connectance Diagram for Paper Converting Operation (PC)

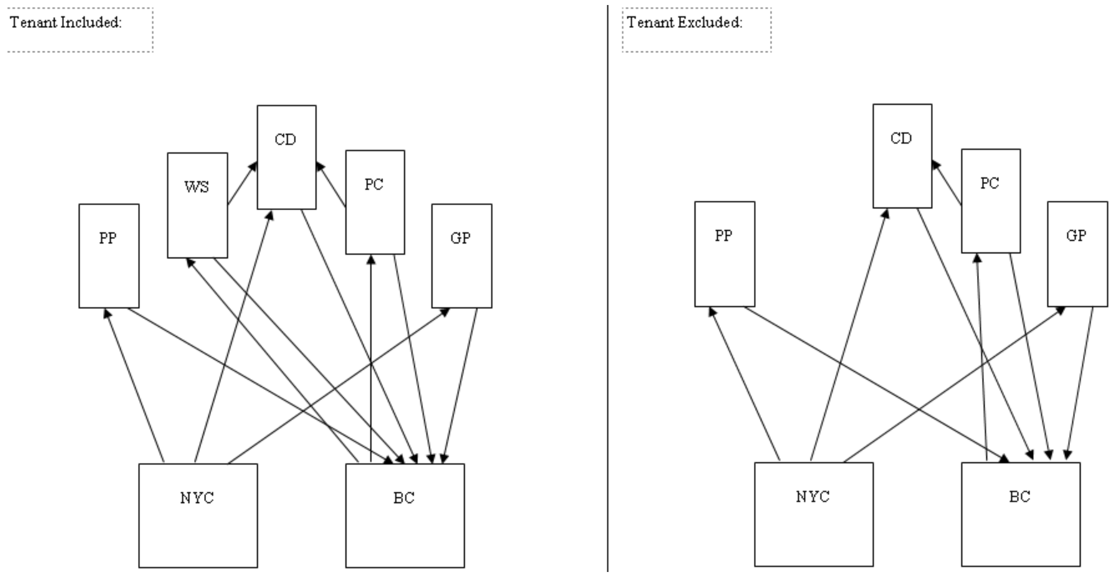


Figure 27: Connectance Diagram for Wood Salvage and Re-milling Operation (WS)

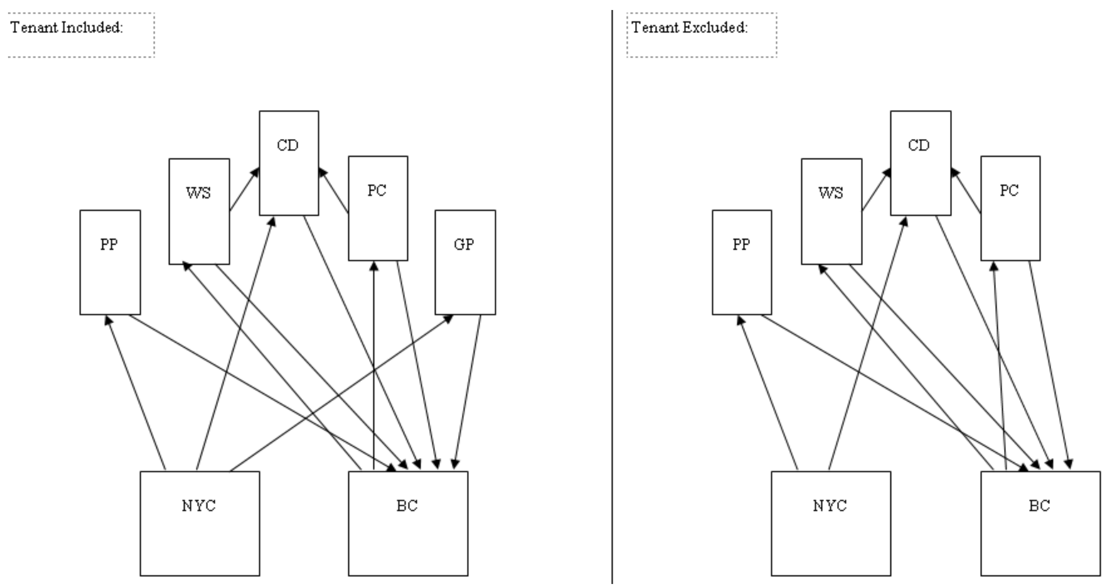


Figure 28: Connectance Diagram for Glass Powder Manufacturing Facility (GP)

Table 47: Oak Point EIP, Potential Tenant Data for Incoming byproducts and materials

INCOMING						
TENANT ALTERNATIVES	**Virgin or Byproduct? (Origin)**	**Recyclable Product**	**Amount**	**Units**	**Method of Transport**	**Source (Orgz. or Company)**
Construction and Demolition (C&D) Debris Recycling Facility	Byproduct (NYC C&D transfer stations)	construction and demolition debris	2,000	tons/day	truck (62,000/yr)	Bronx's five existing C&D transfer stations
Plastics Product Manufacturer	Byproduct	mixed post-consumer and post-industrial recycled plastic waste streams (75%)	126,000,000	lbs/year	barges (70/yr for post-consumer) and rail hopper cars (569/yr for post-industrial scrap)	New York metro area's recyclers (stations), handlers, and producers of plastic
	Virgin	proprietary additives (25%)	42,000,000	lbs/year	rail hopper cars (263/yr)	Undisclosed Supplier
Paper Converting Operation	Byproduct	1 ton "parent rolls" of 100% recycled-content paper (coming from paper mills)	16,050	tons/year	trailers (803, 40K lb max-capacity trucks/yr)	from recycled fiber/paper mills in New York, Pennsylvania and North Carolina
Wood Salvage and Re-milling Operation	Byproduct	timbers and lumber purchased from deconstruction and demolition companies	18,156	tons/year	40' long flatbed trucks (8200/yr)	Purchased from deconstruction and demolition companies in NY
Glass Powder Manufacturing Facility	Byproduct	mixed glass cullet and container glass (2" glass gragments) (requires cleaning and processing)	77,870	tons/year	700-ton capacity barges (111/year)	New York City curbside recycling program
Educational Incubator/Child Care	N/A	N/A	N/A	N/A	N/A	N/A

Table 48: Oak Point EIP, Potential Tenant Data for Outgoing byproducts and materials (including the number of jobs created)

OUTGOING							JOBS
TENANT ALTERNATIVES	Waste or Usable Byproduct?	Recyclable/Produced Product	Amount	Units	Method of Transport	Destination	# Created
Construction and Demolition (C&D) Debris Recycling Facility	Usable Byproduct	sand, gravel, and other "stone" products	1,550	tons/day	1000-ton capacity barges (/yr)	northeastern markets	80
	Usable Byproduct	sand, gravel, and other "stone" products	100	tons/day	dump loaders (40K-lb/truck max capacity)	nearby local markets	
	Usable Byproduct	ferrous and non-ferrous metals	100	tons/day	rail (100 ton/car)	national markets	
			100		dump loaders		
	Waste	slime	50	tons/day	rail (100 ton/car)	landfill	
	Waste	residue waste	100	tons/day	rail (100 ton/car)	landfill	
Plastics Product Manufacturer	Usable Byproduct	industrial composite plastic products like pallets, marine timbers, and railroad ties	168,000,000	lbs/year	1400 flatbed rail cars (each carrying 3 tons)	market for ties among the Northeast's commuter railroads	155
	Waste	Normal commercial trash (office waste paper or lunches)	2,000	lbs/year	rail (100 ton/car)	landfill	
Paper Converting Operation	Usable Byproduct	Finished paper products	15,000	tons/year	dump loaders (750 full (40K lb max) trucks/year)	supply contracts with the federal government and major commercial and institutional buyers	50
	Usable Byproduct	post-production/post-industrial paper scrap	1,050	tons/year	dump loaders (53 trucks/year)	shipped back to paper-mills	
	Byproduct and Waste	Normal commercial trash (office waste paper or lunches) and shipping pallets	1	ton/year	rail hopper cars (100 ton/car)	office waste paper goes to paper mills. Scrap shipping pallets go to the C&D facility.	
			1	ton/year	rail hopper cars (100 ton/car)	Extra waste (50%) goes to landfill	

Table 49: Oak Point EIP, Potential Tenant Data for Outgoing byproducts and materials (including the number of jobs created) (Continued)

OUTGOING (Continued)							JOBS
Wood Salvage and Re-milling Operation	Usable Byproduct	Sell lumber and timber "as-is" or "in the rough" (50% of all outgoing)	15,700	tons/year	flatbed-trucks (3300/year)	lumber mills and timber framing companies worldwide	20
	Usable Byproduct	Heavy timbers, shoring lumber and plywood (25% of all outgoing) - minimal processing required				sold to highway construction, bridge refurbishing, and other contractors throughout Eastern seaboard	
	Usable Byproduct	Remaining 25% of inventory is re-sawn and re-milled into dimensional lumber and blanks for architectural and fine carpentry applications				Archtect and fine carpentry companies (wood makers?) within region	
	Usable Byproduct	wood scraps, sawdust and shavings	2,415		two individual 30-cubic-yard roll-off containers (large truck)	C&D facility and other local users (assumed to be free)	
	Waste	Normal commercial trash	1		rail hopper cars	landfill	
Glass Powder Manufacturing Facility	Usable Byproduct	glass powder (replaces up to 40% of needed Portland cement) - less costly aggregate and daily cover at landfills (U.S. Patent Application Number 20060130707)	54,509	tons/year	~ hopper cars (340/yr) ~ trailor trucks (1362/yr)	nationwide architects, builders, contractors, and concrete and masonry block suppliers	30
	Waste	mixed plastic, paper and metal residual waste	23,361	tons/year	rail hopper cars (292/yr)	Landfill	
Educational Incubator/Child Care	N/A	N/A	N/A	N/A	N/A	N/A	~10

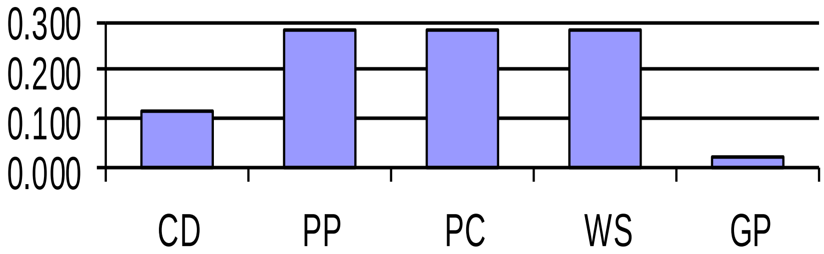


Figure 29: Normalized Score of Alternative Tenants vs. Criterion Sym2

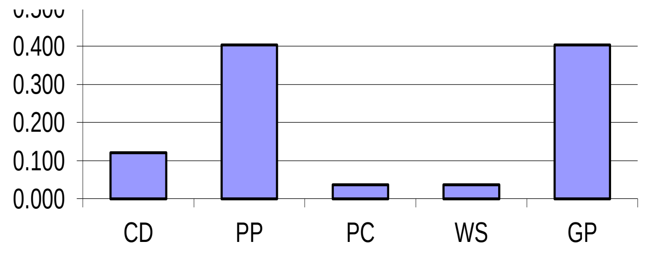


Figure 30: Normalized Score of Alternative Tenants vs. Criterion Eco1

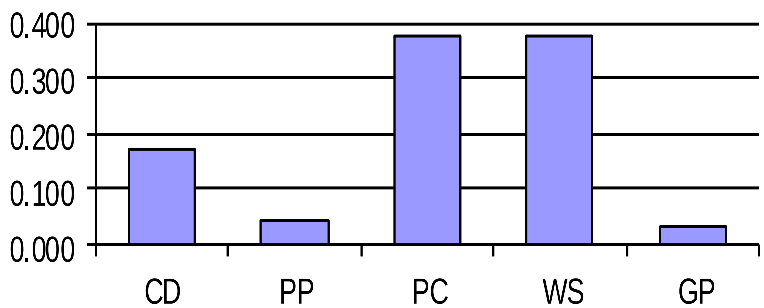


Figure 31: Normalized Score of Alternative Tenants vs. Criterion Com1

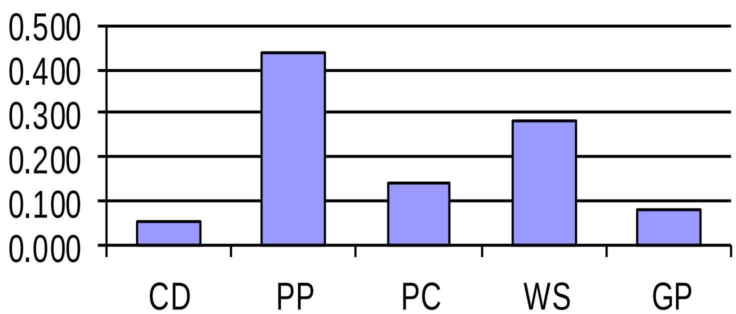


Figure 32: Normalized Score of Alternative Tenants vs. Criterion Env1

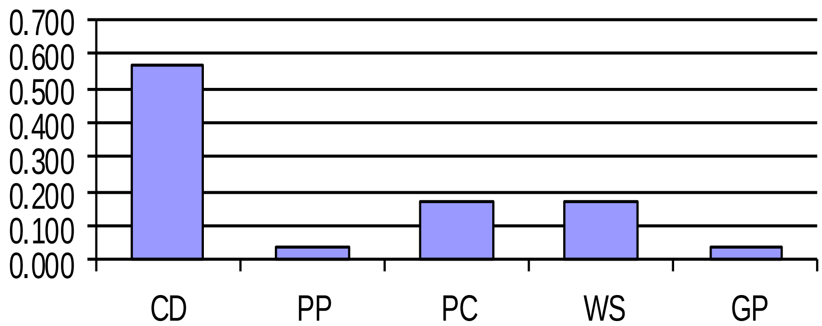


Figure 33: Normalized Score of Alternative Tenants vs. Criterion Sym1

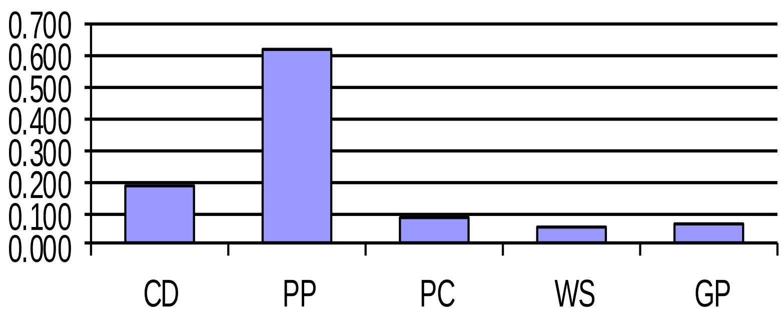


Figure 34: Normalized Score of Alternative Tenants vs. Criterion Eco2

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