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Towards Sustainable Business Parks: a Literature Review and a Systemic Model

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Abstract

In developed countries, business and industrial areas are challenged by various issues such as air pollution, waste handling, resource consumption, infrastructure aging and adequate land rarefaction. Subsequent to the introduction of sustainable development and industrial ecology, the idea to create Eco-Industrial Parks based upon the exchange of resources has been acknowledged as a promising strategy to address these issues. The creation of a materials and energy exchange network through processes coupling, also called industrial symbiosis, is achievable in mainly heavy industrial complexes. Business parks with "lighter" industry or service-based companies can improve their sustainability through different approaches. Other types of collaborations can be envisaged such as shared services for the employees and companies, collective logistics or joint research and development. Moreover, reflections could also be orientated towards the park's design and infrastructure planning. From those observations, a new type of Eco-Industrial Park is introduced: the mixed-use ecopark. The mixed-use ecopark is a more accessi-

ble archetype, better suited to the case of business parks with service-based companies. Arguing that the mixed-use ecopark is systemic, a conceptual framework is proposed following Le Moigne's systemic modeling approach. Systemic modeling describes the mixed-use ecopark through its objectives, its environment and its structure. It gives a robust yet flexible framework for the future development of a sustainability performance measurement system for the mixed-use ecopark.
Keywords: Sustainability, Industrial Ecology, Eco-Industrial Park, Mixed-Use Ecopark, Sustainable Urban Planning, Systemic Modeling

1. Introduction

Growing concerns on several issues such as air and water pollution, resource depletion and the economic and financial crisis have motivated initiatives worldwide to establish sustainability in various fields and contexts. Sustainable development gained worldwide acceptance after the World Commission On Environment and Development (1987) in Rio de Janeiro, Brazil. It is defined as "*a development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". In other words, sustainability's goal is to meet human needs without undermining the integrity and stability of natural systems. Sustainability can be broken down into three pillars, also called "triple bottom-line", namely social, economic and environmental aspects. Since then, with the local applications of Agenda 21, the will to move towards sustainable development has become particularly strong at the regional and local levels (United Nations, 1992).

One of the major challenges for communities is the development of re-

spectful and productive business parks. According to the United Nations Industrial Development Organization, a business park is: "*A tract of land developed and subdivided into plots according to a comprehensive plan with provision for roads, transport, and public utilities for the use of a group of industrialists*" (United Nations Industrial Development Organization, 1997). In this article, for the sake of clarity, a business park with mostly heavy industrial activities is called an "industrial park" and a business park with lighter industries or that is solely service-based is called a "mixed industrial park" as proposed by Lambert and Boons (2002).

The creation of industrial and mixed industrial parks resulted from the generalization of the urban planning concept called "zoning" which is the process of dividing land between different areas specific to their use in order to set planning guidelines for urban development. This concept was developed by planners and architects who wanted to clear up the frictions between industrial development and the quality of urban life. Lambert and Boons (2002) indicated that this concept is now the classical model for planning and developing cities in Europe since it was recommended by Le Corbusier in 1928. They indicate that the idea behind the distancing of heavy industrial activity from others is that industry requires specific infrastructures that are not compatible with the urban fabric and that its impacts need to be separated from residential areas, for comfort, health and safety reasons. They estimate that in the case of mixed industrial parks, the intention is to provide large floor plates, located near main roads, at a cheaper cost (Lambert and Boons, 2002).

Nowadays, business parks need to transform themselves in order to man-

age with the economic, environmental and social shortcomings stemming from waste handling, resource consumption, infrastructure aging, land rarefaction, etc. (Lambert and Boons, 2002). For this reason, much is being done today to propose more sustainable business parks. Several disciplines and key concepts are related to this endeavor such as industrial ecology and sustainable urban planning.

The first contribution of this article is an analysis of the multidisciplinary literature positioning the concepts surrounding the sustainability of business parks that leads to the proposal of a new model of sustainable business park: the mixed-use ecopark (MUE). The second contribution of this article is the systemic modeling of the MUE. Indeed, a conceptual framework of the MUE is required in order to support its definition. Systemic modeling was chosen for this description because it can apprehend the MUE through the interactions of its components and logically define its behavior and objectives. The main objective of this article is to set the basis for the development of a sustainability performance measurement system (SPMS) for the MUE's management.

This article is structured as follows. Section 2 describes the method used for the literature review on the concept of sustainability in industrial parks and the selection of business parks studied. Section 3 presents the results from the literature review from the perspective of two different disciplines. Subsection 3.1 presents and positions concepts relating to the eco-industrial park (EIP) and Subsection 3.2 presents the principles of sustainable urban planning and development. Following this literature review, the observation of the case studies and the proposal of a new concept called MUE are

presented in Section 4. Then, a conceptual framework of the MUE, using systemic modeling, is proposed in Section 5 and the potential for this approach to set the basis of a SPMS for the MUE is discussed. Section 6 concludes this article.

2. Materials and Methods

2.1. Literature review on the sustainability of business parks

The literature review is carried in a cascading approach starting with the definition of the EIP. This review is narrative and multidisciplinary, investigating the topic of business parks' sustainability in the fields of industrial ecology and urban planning. Peer-reviewed papers from indexed publications were selected along with grey literature sources. Moreover, when clearly identified for a given concept, the seminal paper is mentioned.

The keywords used are the following: "*sustainable industrial park*," "*sustainable business park*," "*eco-industrial park*," "*industrial ecology*," "*circular economy*," "*industrial symbiosis*," "*sustainable urban planning*," "*eco-city*" and "*eco-neighborhood*." The search was executed with one or two keywords on Google Scholar and in the Scopus database.

In total, 116 documents were consulted between September and March 2018. On those 113 document 92 dealt with topics related to the field of industrial ecology and 21 dealt with the topic of sustainable urban planning. On the 92 documents from the industrial ecology literature, 38 were focused on the subject of Eco-Industrial Parks specifically.

2.2. Case Studies

Three business parks were investigated for this study: Savoie Technolac and Chambéry's disctrict La Cassine in Savoie, France and Daniel Gaudreau ecopark in Quebec, Canada. This study is attached to the context of two regions: Savoie in France and Centre-du-Québec in Canada. Indeed, during the last three decades the city of Chambéry in Savoie went through a progressive de-industrialization. Despite the land pressure caused by the proximity of the mountains and the population growth, more than 50 hectare of brownfield close to the city center are abandoned. Those sites offer potential for urban development integrating business parks. The development of those business parks must take the geographical, economic, social, environmental and energy local context into account. It must be federating, robust, concerned with the quality of life and the environment and likely to create an endogenous and competitive territorial development. In the Centre-du-Québec region, the city of Victoriaville faces similar challenges with the development of an eco-industrial park. Victoriaville engaged in this development in a different context with the intention to attract and retain the labour they currently lack of. For those reasons, the case studies were volunteers to be part of a research project on the performance evaluation and design of decision-making support tools for the development of sustainable business parks. Moreover, the case studies were selected because they offers diversity in the following terms.

- Size : Savoie Technolac have 250 tenants when Daniel Gaudreau ecopark only have 2.
- Developement stage : La Cassine is still at the design phase, Daniel

Gaudreau have currently sold 10% of its lots and Savoie Technolac is a complete business park wishing to extend itself in the near future.

- Geography : Two case studies are located in France and one is located in Canada allowing for a comparison between both culture and policies. Moreover La Cassine is located in Chambéry's center whereas the two other case studies are built in the periphery of the city.

- Targeted companies : Savoie Technolac is specialized in the building, energy and electronic sector, La Cassine wants to attract service companies and local artisans and lastly, Daniel Gaudreau ecopark accepts light industries from all sectors.

3. Results from the literature review on sustainability in business parks

3.1. Sustainable development through industrial ecology: eco-industrial parks and other initiatives

The starting point of this literature review is industrial ecology (IE) and its application at the business park scale: the EIP. This section defines these concepts and other similar approaches and strategies addressing the sustainability of industrial and mixed industrial parks.

3.1.1. Industrial ecology

IE is the discipline promoting the concept of industrial ecosystems, which derives from a metaphor of biological ecosystems and proposes solutions aimed at improving the industry's environmental impact (Frosch and Gallopoulos, 1989; Erkman, 1997). An industrial ecosystem should develop an

optimal web for the recycling and cascading of materials and energy, mimicking food webs in the natural ecosystem (Korhonen, 2001). The essential idea, also called "roundput" by Korkhonen (Korhonen, 2001; Korhonen and Snäkin, 2005; Korhonen, 2007), is that the effluents of a company become the input of another to minimize virgin input. The ideal industrial ecosystem would operate in a closed loop of recycling and reusing so that it does not produce any waste (Ayres and Ayres, 2002).

IE moves away from the preventive approaches that consist of reducing virgin materials or energy inputs and reducing waste (Lovins et al., 2007). Contrarily to cleaner production wich focuses on companies (Hens et al., 2018), it is applicable at all levels from micro to macro. IE offers the basis for achieving sustainability through cooperation between waste-producing and waste-consuming processes. It considers society's metabolism as a whole rather than optimizing each of its components independently. The application of IE should provide a win-win-win outcome for the community, where the environmental impact of businesses is lessened, achieving economic and social benefits (Dunn and Steinemann, 1998).

Applications of IE concepts are mostly encountered at the local or regional scale through the form of eco-industrial development or industrial symbiosis (IS) (Gibbs et al., 2005; Deutz and Gibbs, 2008). As defined by Chertow (2000): "*Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantages involving physical exchange of materials, energy, water, and/or by-products. The keys to IS are collaboration and the synergistic possibilities offered by geographical proximity.*"

IE and IS are often associated with the circular economy concept (Ellen

MacArthur Foundation, 2013). A circular economy promotes the shift from the traditional, linear, open-ended economic system to a circular economic system, with "closing-the-loop" production patterns. A first theoretical framework for the circular economy was proposed by the environmental economists Pearce and Turner (1990). The second law of thermodynamics and Georgescu Roegen's theory on the irreversible exhaustion of natural resources through economic activity serve as the major arguments for the need to shift to a circular system (Georgescu-Roegen, 1971). IE was introduced at the same time as the circular economy concept with Frosch and Gallopoulos publishing their seminal article the same year that Pearce and Turner published theirs. Nevertheless, some authors considered that the circular economy concept takes its roots in IE and that it builds on IE's concepts for the industrial system, scaling them up for the whole economic system (Ghisellini et al., 2016; Saavedra et al., 2017). It seems that circular economy's focus is wider than IE and the analysis of flows in industrial systems.

3.1.2. Eco-industrial park

At the local scale, a business park implementing a long-term IE strategy is called an EIP (Lowe and Evans, 1995; Cohen-Rosenthal et al., 1996; Desrochers, 2001). A famous definition of the EIP was proposed in 1997 by the U.S President Council on Sustainable Development (1997). They defined an EIP as: "*A community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, energy, infrastructure and natural habitat), leading to economic gains, improvements in environmental quality and equitable enhancement of human resources for businesses and the local community.*"

Pellenbarg (2002) proposed the following characteristics to identify an EIP:

- joint use of facilities and collective facilities;
- closing material cycles through the use of waste materials;
- relocating firms for a more efficient use of space;
- clustering firms that are complementary in terms of economy and ecology.

Tudor et al. (2007) examined the different options of cooperation between those aiming at sustainable production processes (or streams) and those aiming at sustainable site arrangements (or parks). There seems to be a debate on the defining characteristics of an EIP, but the symbiosis, or "roundput," appears to be its ultimate goal (Deutz and Gibbs, 2008).

The most famous EIP is Kalundborg's EIP in Denmark. It has been abundantly documented in the IE literature as the best example of IS and serves as evidence of the benefits provided by the implementation of IE in a geographically restrained space (Lowe and Evans, 1995; Chertow, 2000; Gibbs et al., 2005). A network of energy and materials exchanges has organically grown in Kalundborg industrial park between the city, a power plant, a refinery, a pharmaceutical plant, a gypsum board manufacturer and a waste treatment plant. This has already helped to save on a consequential amount of resources and to decrease production of waste (Jacobsen, 2006).

Another model of industrial parks cooperating to gain various economic benefits is the concept of industrial clusters. Porter (1998) defines an industrial cluster as: "*a geographic concentration of interconnected companies,*

specialized suppliers, service providers, firms in related industries and associated institutions (e.g., universities, standard agencies, trade associations) in a particular field that compete but also cooperate." The EIP can also focus its strategy on one particular field, but the difference between the EIP and industrial clusters is that the objective of an industrial cluster is mainly, if not solely, economic and thus does not address all the objectives of sustainability.

It should be noted that all of the concepts and approaches described in this article are specifically orientated towards the particular case of geographically constrained collections of business. Other concepts and analogous approaches can be found in the literature. Particularly, in the supply chain management community, very similar approaches such as environmental management, design for the environment, product stewardship, green purchasing and reverse logistics are used to improve the sustainability of supply chains (Leigh and Li, 2015). Excluding geographical proximity, the similarities between supply chains and business parks could be used for the development of sustainable business parks drawing from supply chain management experience (Le Tellier et al., 2017).

Having defined the various concepts and disciplines surrounding the EIP paradigm, these concepts are positioned in Figure 1. sustainable development is at the root of most explorations in the circular economy concept and IE. Knowing that the focus of the circular economy concept is wider than the industrial system, it was placed above IE, even if they were both introduced the same year. It should also be noted that other concepts relating to the circular economy and IE were added to Figure 1 as an illustration of the variety of potential approaches of both fields.

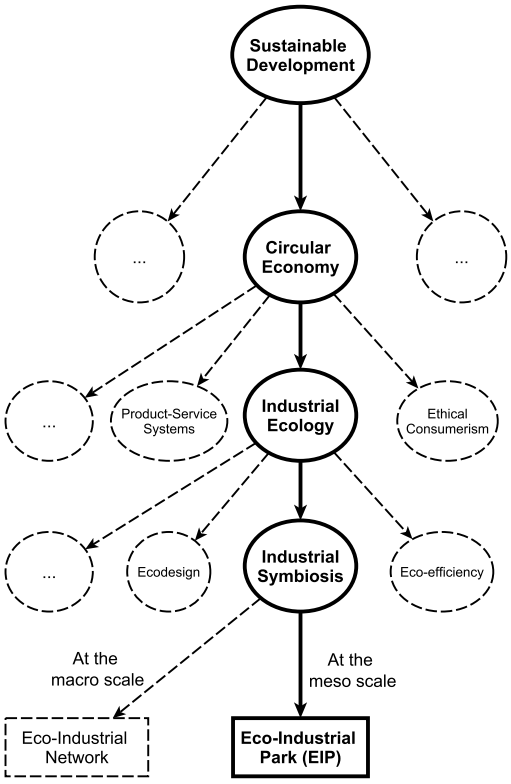


Figure 1: Position of the EIP concepts

3.1.3. Other initiatives of sustainable business parks documented in the literature

The Research Triangle Institute (1996) identified seven types of eco-park development that should not be considered equivalent to an EIP. These eco-parks are presented in Table 1. The Research Triangle Institute consider that: "*An EIP could include any of these features. But the critical element in defining an EIP should be the interactions among its member businesses and between them and their natural environment*," or in other words, that only IS is the defining element of an EIP.

Table 1: Sustainable industrial developments that are not an EIP (Research Triangle Institute, 1996)

1	Single by-product exchange pattern or network of exchanges;
2	Recycling business cluster (e.g. resource recovery recycling companies);
3	Collection of environmental technology companies;
4	Collection of companies making "green" products;
5	Industrial park designed around a single environmental theme (e.g., a solar energy-driven park);
6	Park with environmentally friendly infrastructure or construction;
7	Mixed-use development (e.g., industrial, commercial and residential).

In Italy, the concept of ecologically equipped industrial area (EEIA) was introduced by a legislative decree in 1998. According to Taddeo (2016), the EEIA is a geographically delimited production area with high environmental quality standards. Taddeo argues that the EEIA displays a number of limits preventing it from becoming a generalizable model, specifically its initial investment with a long return time and its rigidity. However, it can play a role in the implementation of the EIP model in Italy by encouraging collaboration between co-located companies and helping to overcome the regulatory limits preventing waste exchange.

In Belgium, efforts have been made by the Walloon government to encourage more sustainable strategies for the development of business parks with the introduction of the "eco-zoning" concept. Van der Kraa et al.

(2011) give the following definition of eco-zoning: "*Economic activity area, pro-actively managed by the association of its company members, positively interacting with its environment, and where urban planning, environmental management and IE contribute to optimize the use of land, materials and energy, to support the performance and economic dynamic of the company members and the community and to lower the local environmental impacts.*" The main difference between an EIP and eco-zoning is that the latter goes beyond IE. Indeed, the eco-zoning concept addresses issues related to the planning and management of a business park while the EIP's main objective is to create a mature IS.

As can be seen, both the EEIA and eco-zoning were created in a local context to respond to local needs and realities.

Lambert and Boons (2002) proposed a typology of EIP initiatives differentiating the mixed industrial park from the heavy industrial complex. They define the mixed industrial park as "*industrial activities, mainly small- and medium-sized enterprises, which are concentrated in dedicated areas, of a very diverse nature with no or little coupling of production processes.*" Having identified this particular type of industrial park, the authors argue that their impact on the environment and country planning is non-negligible even if it is insufficiently examined. Indeed, they argue that once the lots are issued, the selection of companies and trivial collective managements such as traffic control, fire protection and signposting are absent. They then propose two types of mixed industrial park initiative developed under the banner of IE and EIPs:

1. greenfield development, which addresses ecological issues in the differ-

ent stages of the development process;

2. brownfield development, which is the revitalization of an existing area, taking the reduction of the environmental impact into account.

3.2. Sustainable urban planning and development

Following the presentation of different concepts relating to IE in industrial parks, it is suggested that the sustainability of industrial park planning could also be improved. Industrial and mixed industrial parks could benefit by integrating notions of sustainable planning into their design, development and performance evaluation. To support this proposal, the following section outlines and briefly introduces urban sustainability and its application at the city scale ("eco-cities") and the district scale ("ecodisctrict" or "eco-neighborhood").

3.2.1. Emergence of sustainability in procedural planning theory

Urban planning is a scientific and professional field concerned with the design of the urban environment. More precisely, urban planners handle the development of buildings, the use of land, and the design of urban infrastructures such as transportation, communications, and distribution networks (Merlin, 2002). Urban planning is an independent professional discipline relating to different fields such as architecture, landscape architecture, civil engineering, and public administration.

Since its introduction in 1987, the concept of sustainability has been implemented in the urban planning field (for a historical review of trends and theoretical approaches leading to urban sustainability, see (Bayulken and Huisingh, 2015)). Nowadays, urban planners in most European cities focus on

reaching a certain level of sustainability and researchers work to define what urban sustainability is and how to reach it. Aiming at the triple bottom-line, urban sustainability spans economic concerns - investment and operating costs - environmental concerns - mobility, waste handling, energy and water management and biodiversity preservation - and social concerns - political and social solidarity and equality, comfort, citizenship, governance. Campbell (1996) considers urban sustainability as the trade-off between the three conflicts resulting from the triple bottom-line: between economic growth and equity arises a conflict of property; between equity and environment protection arises a conflict of development; between economic growth and environment protection arises a conflict around resource consumption. At the center of this conflict triangle is the sustainable urban development that Campbell qualifies as "green, profitable and fair." Sustainability is often seen as an elusive goal, but more than a goal in itself, it is the opportunity to understand, to increase awareness and responsibility, and finally to rethink lifestyles and their physical impacts on cities and the environment.

3.2.2. Eco-city, ecodistrict and related concepts

The eco-city and similar concepts such as "sustainable city", "resilient city" and "low-carbon-city", are (more or less) the application of sustainability to the planning of a city. De Jong et al. (2015) interpret these concepts as initiatives aimed at upgrading urban infrastructure and services, in an effort to create better environmental, social and economic conditions and to enhance cities' attractiveness as well as their competitiveness.

At a smaller scale, sustainable urban planning projects adapted to a neighborhood are called ecodistricts or eco-neighborhoods (Næss, 2001). Ex-

amples of famous ecodistricts are Vauban in Freiburg, Germany (Schroepfer and Hee, 2008), BedZed in London, UK (Chance, 2009) and BO01 in Malmö, Sweden (Austin, 2009). In France, and especially in Paris, many eco-neighborhood projects have been undertaken. The popularity of the concept can be explained by the support given by the French government through the addition of new regulations and especially the *Grenelle 2 law* (About-de Chastenet et al., 2016; Boutaud, 2010).

Other than scale, according to Joss (2011), eco-city endeavors can be differentiated by types of urban development (such as new developments of entire urban centers built from scratch, urban "infill" developments - new districts built on brownfield sites, or "retrofit" developments, regenerating and upgrading existing urban areas), phases of development (pilot/planning phase, under construction, or implemented) and key implementation mode (through technological innovation, integrated sustainability plan, or civic engagement). Joss (2015) also proposed dimensions, or areas of interest, for the eco-city based on the sustainability triple bottom-line applied to the urban context. These dimensions are sorted into five categories: environmental sustainability, economic sustainability, social sustainability, urban design and systems and urban governance. Each eco-city can address different criteria of these categories with specific related targets. These details are presented in Table 2. It should be noted that an initiative does not have to apply every element of sustainability; decision-makers can choose a broad approach but can also focus on a limited set of key goals. Moreover, these dimensions will impact and require the involvement of several different stakeholders such as regional and local governments, public service providers and citizens. This

framework is only one proposal among others since there are no international frameworks or standards defining the eco-city or ecodistrict.

Having defined the notion of urban sustainability, it is suggested that the concept of ecodistrict could be transposed to business parks even if they may be geographically remote from the city. Indeed, planning a business park can integrate some of the same sustainability elements as those proposed for an ecodistrict, for instance, smart technologies or sustainable storm water management. For a business park, strategies relating to sustainable urban development and IE are complementary even if undertaken at different time scales. Sustainable planning of the park will be an important target at the early stages of the project and the creation of a symbiosis should be a major concern during the selection of companies and the animation of the collaboration in the park.

4. Observation and proposal of a new concept of sustainable business park

In this section, the results from the observation of the case studies are presented. Following these observations and the literature review, a new concept of sustainable business park is proposed: the MUE.

4.1. Observation of initiatives towards sustainable business parks

Three initiatives of sustainable business parks were observed by the authors: Savoie Technolac in Le-Bourget-du-Lac, France (Chambéry-Grand Lac Economie, 2018b), La Cassine in Chambéry, France (Chambéry-Grand Lac Economie, 2018a) and Daniel Gaudreau's MUE in Victoriaville, Canada (Corporation de Développement Economique de Victoriaville et de sa région,

Table 2: Eco-city dimensions (adapted from Joss (2015))

Categories	Dimensions
Environmental sustainability	CO_2/GHG emission
	Buildings' energy consumption
	Water consumption
	Public transport integration
	Waste handling
	Biodiversity protection
Economic sustainability	Highly skilled, "green" jobs
	Competitiveness and resilience
	Smart technology/innovation
	Well-being
	Housing affordability
	Urban agriculture promotion
Social sustainability	Livability
	Equity
	Civic engagement
	Cultural diversity
Urban design and systems	Housing density
	Multi-scale integration
	Ecosystems management
Urban governance	Multilevel policy coordination
	Public-private partnerships
	Political accountability

2018). The local stakeholders for each business park were questioned on the subject of their respective business parks, their structure and their objectives. Savoie Technolac's stakeholders provided their indicator scorecard and Victoriaville's stakeholders provided their development plan and the approval charter for candidate companies. The private planner in charge of the design of La Cassine provided the results of their preliminary economic and environmental study with the recommendations they made to the decision-makers in charge of the project. Moreover, additional information were provided by the respective internet websites of those business parks.

Savoie Technolac is a French technopole focusing its strategy on the innovation, building and energy sector and, more particularly, the solar energy sector. Companies implanted in Savoie Technolac mostly produce services. They benefit from close proximity to the local university and the strong entrepreneurial dynamic created by the business incubator and growth accelerator. Savoie Technolac does not advertise itself as a sustainable business park, but it has implemented many collaborative sustainable actions over the years. For example, one of their most recent projects doubles their production of renewable energy to an 18,000-person capacity.

Daniel Gaudreau's MUE is located in Victoriaville in the Quebec province of Canada. Built next to a wetland, this young MUE focuses its strategy on sustainable urban planning and architecture and requires its companies to be certified to a local standard on sustainable business practices called Démarche d^2.

Lastly, La Cassine is a district of Chambéry, a 60,000-inhabitant city in the Savoy region in France. The local stakeholders' intention is to rehabilitate

the Cassine district in a mixed industrial park for service companies and small craft enterprises to attract tourists traveling to the Alps or Italy. Their wish is to alleviate the impact of the district on both the environment and the city by adopting a sustainable urban development approach.

In summary, the business parks observed show diversity in their sizes, their companies' activities, their life cycle stages and their cultural and natural environments. Since their companies' production process are rarely compatible, none of these business parks wish to develop an industrial symbiosis based on material substitution synergies. However, all these business parks' stakeholders expressed and enforced an ambition to improve their sustainability through :

- sustainable urban planning and architecture;
- shared services to the employees, such as shared restaurants, child day care, a car-sharing platform etc.;
- collaboration between companies, such as joint logistics, joint research, offices renting, energy substitution synergies (residual heat from data center or private renewable energy production for example) etc.

As a result of this observation, a new concept of sustainable business parks is proposed.

4.2. Proposal for a new concept: the mixed-use ecopark

The IE strategy and the creation of an IS is complicated by the diversity of activities concentrated in some business parks. Companies in the tertiary sector cannot couple production processes and create material synergies. Of

course, synergies can also be created for the sharing of energy. Indeed, even an exclusively service-based business park can create a beneficial exchange of energy between buildings. Moreover, the sharing of services such as restaurants and child care could improve the well-being of the business park's users at a lower cost.

Despite this potential, the creation of a symbiosis is rarely the first goal of most local governments. French and Quebec local governments working on the design and marketing of business parks reported they have close to no power over the already implanted businesses and their practices. Local government can only encourage collaboration by matching businesses. They cannot force implanted companies to cooperate and will not discourage new companies from establishing themselves in their business parks by enforcing coercive rules.

A literature review and observations of sustainable business parks' strategies concluded that the decision-makers' understanding of sustainability is mostly orientated towards the park planning. They endeavor to provide a high-quality business area with a lesser impact on the environment and high social acceptance, providing more jobs and more economic recognition in the long run than its classic counterpart. Moreover, the popularity of the concept of ecodistrict could also explain the desire to plan attractive and sustainable business parks. High-quality business parks are one of the solutions towards attracting jobs, retaining employees, against building land rarefaction, and against competition with other industrial parks.

Arising from the previous analysis of concepts such as the EIP and the ecodistrict, a particular case of sustainable business park called mixed-use

ecopark is proposed. The MUE is a variant of EIP with a stronger emphasis on the sustainability of its planning and development. The MUE shares similar endeavors with the ecodistrict but it is not necessarily a district and it is not designed for mainly residential purposes. Eventually, as can be seen in Figure 2, the MUE is a combination of an EIP and an ecodistrict. By adding this characteristic, a definition for the MUE, based on the one given by the US President's Council on Sustainable for the EIP (U.S President Council on Sustainable Development, 1997) , is introduced. "An MUE is a community of businesses located on a business park planned and built in a sustainable approach, that cooperate with each other and with the local community to efficiently share information, materials, energy or infrastructure, leading to economic gains, improvements in environmental quality and equitable enhancement of human resources for businesses and the local community."

5. Systemic modeling of mixed-use ecopark

5.1. Systemic nature of the MUE

Similar to an EIP (Haskins, 2007; Felicio et al., 2016) and given the systemic nature of cities (Zhao et al., 2013; Masson et al., 2014; Chapman et al., 2016; Pandit et al., 2017), the MUE should be considered as a system. Indeed, the characteristics of natural or human activity systems are the following (Chapman et al., 2016):

1. A system is an *integrated whole* that is more than the sum of its parts;
2. A system is comprised of *nested systems* at a range of scales;
3. A system is *self-organizing*, it can regulate itself in response to changing external conditions;

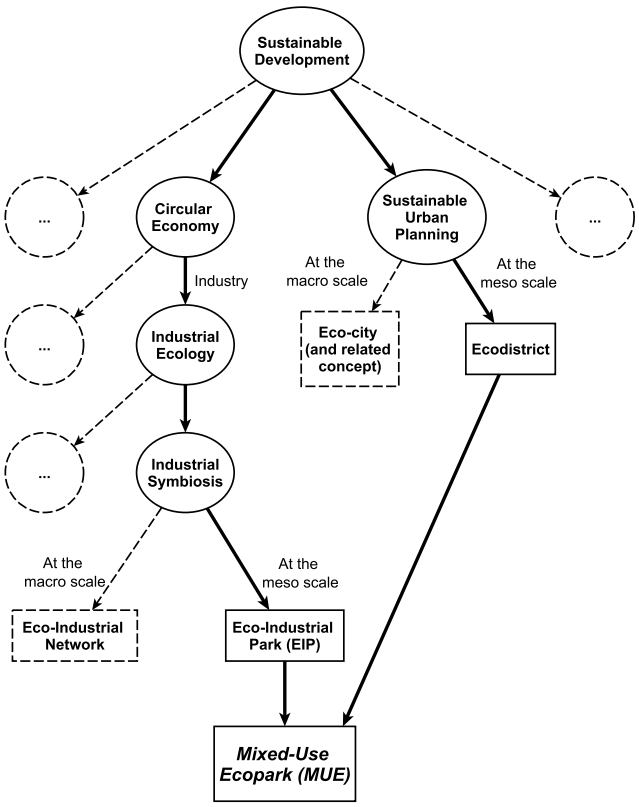


Figure 2: Emergence of the MUE within its founding concepts

4. A system's behavior is *complex*, non-linear and seldom stable;
5. A system is *resilient*.

Since the MUE corresponds to all these characteristics, it is suggested describing it through systemic modeling. Indeed, understanding the systemic nature of the MUE will benefit the definition of its conceptual framework.

5.2. Method

The chosen systemic modeling approach is the one proposed by Le Moigne since his work revolves around artificial systems. His approach to describing

an artificial system offers a coherent methodology to formulate a conceptual framework. Le Moigne (1994) defines a system as: "*The representation of an active phenomenon, perceived as identifiable by its projects, in an active environment, in which it operates and transforms itself teleologically.*" His approach consists of describing a system through several characteristics that are summarized in the following list. These characteristics will be further explained as this modeling approach is unfolded, and a summary will be given in Table 3.

1. *Finality*: the finality of the system at the highest level of abstraction. It reflects the observer's idea of the system's mission.
2. *Environment*: the components interacting with the system and these interactions.
3. *Structure*: the organization of the subsystems, entities and internal interactions that constitute the system.
4. *Objectives*: the objectives set to attain the finality, described for at least two levels: exogenous (the system and its environment) and endogenous (inside the system).
5. *Behavior*: the normal operation of the system and its transformation when its objectives cannot be reached.

5.3. Description of the systemic model of an MUE

5.3.1. Finality

The observer of the MUE is its *Governing_Body*. As its name indicates, the *Governing_Body* is the decision maker for the MUE's development according to a predefined, specific strategy. This body can be composed of several

actors with different individual goals, shifting during the different stages of the MUE's development. It can be composed of public or private investors, planners, local governments, designated decision makers of the MUE, etc. Another role of the *Governing_Body* is to be the animator of the MUE and the instigator of the collaboration between its members.

For example, in the case of Savoie Technolac, the *Governing_Body* is a union of the local urban agglomerations' governance and of the regional governance. This union delegated the planning of the park to a developer but was strongly implicated in the animation of a collaboration between members. In this union, an accreditation committee ruled on the companies' permit applications. Indeed, some companies cannot join Savoie Technolac as they have to comply to predetermined criteria, especially regarding their activity sector. Being an expert in the innovation and energy sector, Savoie Technolac favored companies working in this area.

To be in accordance with its definition, the finality of an MUE should be sustainability. Sustainability fits Le Moigne's idea of finality perfectly since it is a process of continuous improvement through decision making through interactive learning. To be sustainable, a MUE should seek to balance its performance in each of the three pillars of sustainability. This interpretation of sustainability, favoring consensus over the outstanding achievement of only one target, lies outside the weak vs strong sustainability paradigm. Weak sustainability assumes that natural and artificial capital can be substituted, whereas strong sustainability assumes they cannot (Daly and Cobb, 1994; Dietz and Neumayer, 2007; Chandrakumar and McLaren, 2018). Moreover, this interpretation of sustainability grants an equally important weight to each

pillar and more notably to the social sustainability of the MUE (Dempsey et al., 2011).

5.3.2. Environment

As an MUE is a collection of companies, these companies necessarily interact with entities, such as suppliers and clients, implanted outside the MUE. This collection of external suppliers and clients is a part of the system's environment. Entities other than suppliers and clients can influence the behavior of the MUE's companies, but the goal of modeling here is not to give an exhaustive representation of the environment of a company. It should be noted that since the MUE can be exclusively service-based, some MUEs can be integrated into the city where it can unfold new synergies with the residents. In this case, those residents can become new elements of the MUE's environment in the form of clients or suppliers.

Naturally, being the observer of the MUE, the *Governing_Body* is a part of its environment.

5.3.3. Structure

As was established by its definition, in a macroscopic perspective, the MUE is composed of two subsystems. This structure and its relations with the environment is illustrated in Figure 3.

The first subsystem is called *Public_Space*, it represents all the public land and the public infrastructure on this land, such as public green areas, public parking, roads or networks. This *Public_Space* provides a service to the companies who pay for it as taxes and fees, directly or indirectly to the *Governing_Body*, which provides its design and maintenance. It should be

noted that besides the companies, some clients, as visitors, can access the *Public_Space* of the MUE.

The second subsystem is called *Members*. It is composed of two types of entities: "*company*" and "*building*."

1. *company*: In this model, a *company* includes the part of a private company implanted on the MUE with its employees but not its premises. A *company* can be in the secondary or tertiary sector, of any type or size. For example, Savoie Technolac presently contains around 250 companies.
2. *building*: A *building* comprises a building and its land with any private infrastructure such as parking places. In some cases, a company only rents space and does not own the building that it is implanted in. Moreover, several companies could be renting space in the same building. As an illustration, Savoie Technolac contains 55 buildings.

To be considered an MUE, the system should have a minimum of two companies and two buildings. The differentiation of *company* and *building* entities will allow defining specific objectives for both.

The *Members* subsystem logically interacts with other systems such as *Suppliers* and *Clients* outside of the MUE, but the main advantage of the MUE is that many mutually beneficial interactions occur inside the subsystem. Figure 4 gives an example of the complexity of these interactions, both with the environment (Figure 4a) and inside the MUE (Figure 4b).

The interactions can occur between the entities, the subsystems and the environment. An interaction can be broken down into three elements: product, service and financial elements. The product element of an interaction

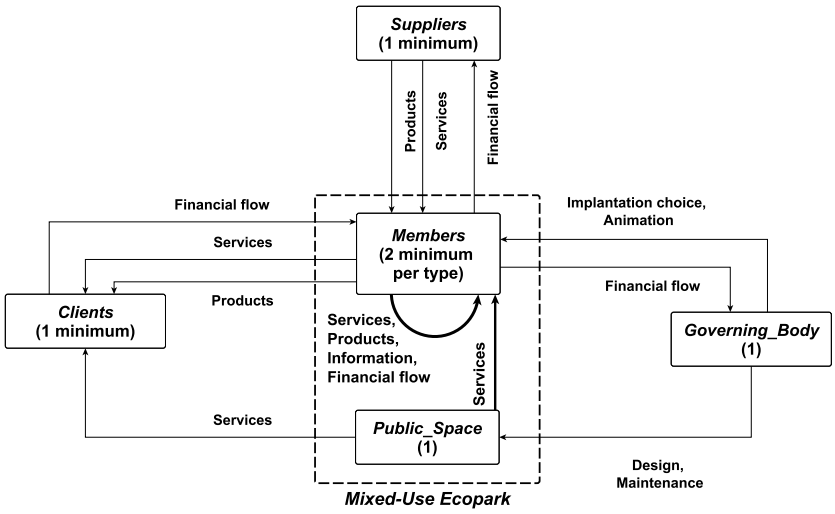
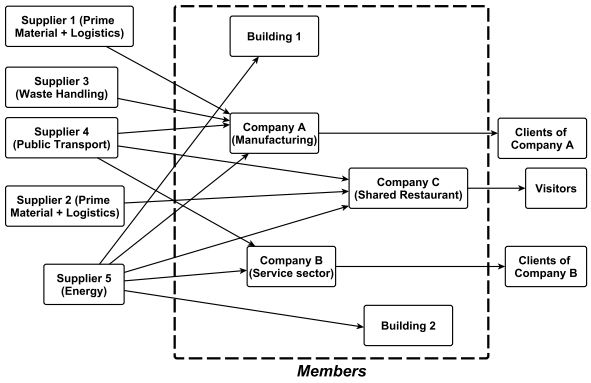
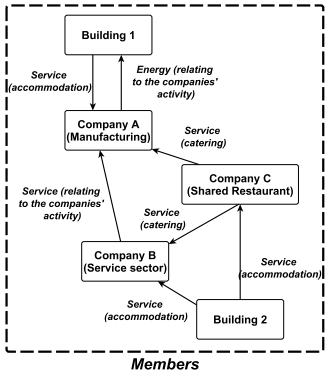


Figure 3: Structure of the MUE

concerns the exchange of energy or material, whether raw material, components, products, by-products, coproducts or waste. In the case of an exchange of products, the service element of the interaction is the transport. The service part of an interaction can be the main component of the interaction, for example renting a company its premises or subcontracting to another company of the MUE. Lastly, the financial element is when the interaction occurs with a financial compensation. In Figure 3 and 4, the interactions are represented by simple arrows pointing to the entity giving a financial compensation and/or receiving a service. For example, the waste handling facility receives waste from company A (product element), processes them (service element) and gets paid for it (financial compensation). In this case, the interaction arrow points to company A. Following this logic, a waste handling facility is a supplier, even if it receives material.



(a) External interactions (with suppliers and clients)



(b) Internal interactions

Figure 4: Illustration of external and internal interactions.

5.3.4. Objectives

The objectives set to achieve the ultimate goal can be described for at least two scales. First, some exogenous objectives characterize the expected outputs of the systems from the environment. Secondly, some endogenous objectives characterize the organization of the system needed to achieve the exogenous objectives.

To achieve these exogenous objectives, the MUE fixes some endogenous

objectives related to its different entities. These endogenous objectives are specific for each MUE while the exogenous objectives are generic to an MUE and therefore cannot be altered. The endogenous objectives will likely be consistent with the particular strategy and theme of the MUE.

5.3.5. Behavior

A system can adopt two different behaviors: operation and transformation. The system operates when it elaborates its outputs in accordance with its exogenous objectives. When it can no longer reach its exogenous objectives, it needs to transform itself by updating its structure. Two extreme cases of transformation are the initial creation and the final removal of a system.

The operation of the MUE is when the subsystems or entities operate by satisfying the exogenous objectives. The transformation is the updating of its structure by revising its endogenous objectives, such as the choice of a new strategy or the change of regulations.

As a system, the MUE consists of nested systems, and its entities' behavior is also either operation or transformation. Transformation of an entity such as the arrival or the departure of a company is part of the normal operation of a MUE. Indeed, welcoming new companies should not require transforming the whole structure of the system. In Savoie Technolac, new companies come and go every year and those modifications constitute the normal operation of the MUE.

Table 3: Summary of the systemic modeling characteristics of the MUE

Characteristics		Modeling of the MUE
1. Finality		Sustainability
2. Environment		*Suppliers*, *Clients* and *Governing_Body*
3. Structure		*Public_Space* and *Members* (*company* and *building*)
4. Objectives	Exogenous	Economic sustainability
		Social sustainability
		Environmental sustainability
		Balance between the three pillars of sustainability
		Continuous Improvement
	Endogenous	Specific to each MUE
5. Behaviour	Operation	Operation of the entities satisfying its exogenous objectives
	Transformation	Evolution of the MUE's structure and its endogenous objectives

5.4. Discussion

The systemic modeling approach presented is an appropriate model for the representation of the MUE. It is generic, it can be expanded if necessary and allows examining the MUE at different levels of abstraction. In future work, this conceptual framework will enable the development of a SPMS for the MUE. The notion of SPMS emerged from the evolution of the performance measurement system concept (Neely et al., 2005; Searcy, 2012), which is "*a multi-criteria instrument, made of a set of performance expressions [...] to be consistently organized with respect to the objectives of [a] company*" (Clivillé et al., 2007). The existing literature on SPMSs is focused on corporate sustainability measurement (Vanleer et al., 2016), with its most famous example being the sustainable balanced scorecard (Hubbard, 2009). As a MUE is different system, with different objectives and stakeholders, it

requires a bespoke SPMSs.

Existing performance measurement methods have been designed for the EIP. To the best of our knowledge, these methods focus primarily on specific aspects of the EIP's performance such as eco-efficiency (Fan et al., 2017), circular economy (Zhao et al., 2017), industrial symbiosis (Felicio et al., 2016; Valenzuela-Venegas et al., 2016), life cycle assessment (Boix et al., 2017) and environmental impact (Pilouk and Koottatep, 2017). In a similar manner, sustainability assessment of an urban planning project does not fully account for the wide scope of the MUE's performance because it does not focus on companies' collaboration and symbiosis (He et al., 2011).

Since the MUE is an integrated concept, its SPMS should address performance within a wide viewpoint. From this standpoint, systemic modeling provides a structure to design the MUE's SPMS. Indeed, systemic modeling gives a robust yet flexible framework to define the objectives and evaluate performance. Besides defining performance indicators for the whole system, indicators can be expressed for each type of entity - *building*, *company*, and the *Public_Space* - and for each type of interaction - *building* to *company*, *company* to *company*, *company* to *Public_Space*. This will make it possible to measure the MUE's performance within a global approach.

6. Concluding remarks

In this paper, an analysis of the EIP's founding concepts led to the proposal of a framework positioning the EIP, helping the navigation in the complicated field of IE. From this analysis and observations, it was argued that the EIP is not always the most adequate model when improving the sustain-

ability of business parks. The coupling of production processes, the heart of IS, is not the only target for business parks, including office parks and commercial parks. Based on the belief that sustainable planning of the area is an important asset to provide high-quality, high-performance and green mixed industrial parks, a brief introduction of the field was unfolded by characterizing the eco-city and the ecodistrict. A new paradigm, called the MUE, was proposed, blending the philosophy of the EIP with sustainable urban planning. The MUE is an integrated archetype of a sustainable business park. The MUE was defined and modeled taking into account its systemic nature. This systemic modeling approach offers a conceptual framework of the MUE.

The perspective of this systemic modeling approach is to create a baseline for the definition and evaluation of the MUE's performance, as a tool helping local governments with the sustainable development and management of their business parks. Capitalizing on successful experiences, performance indicators and their aggregation support the decision-making process by monitoring an MUE's development. Performance evaluation will also be a useful means to promote the benefits of collaboration initiatives among an MUE's members and stimulate sustainable planning of the park. Future work will define a system of coherent indicators to measure an MUE's performance. Once potential indicators are defined, the MUE's decision makers will be able to set targets in accordance with their specific strategy and to monitor their achievement. Overall, this future SPMS is intended to support a quick, easy and flexible evaluation. Moreover, this SPMS is expected to be complimentary to existing specific sustainability assessment methods designed for the EIP and urban planning project.

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