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## Conceptual Framework and Principles for Selection and Definition of Sustainability Indicators: A Study Applied at Ecoinnovation in Smartparks Project (Spain and Brazil)

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### Abstract

This study is inserted in jointly developed project (Eco-innovation in Smartparks) with researchers from Spanish and Brazilian universities (Universidade de São Paulo, Universidade Federal de São Carlos e Universitat Autònoma de Barcelona), aiming to define and to propose specific tools and indicators to contribute for addressing sustainability from the perspective of Ecoinnovation in Smartparks. The concept of Eco-innovation in Smartparks is a proposal that seeks to develop and to apply (in an innovative, integrated and significant way, with an improvement of production processes) new sustainable approaches of conceiving planning and territorial management, integrating symbiosis in industrial, urban and agricultural fields. The concept of Eco-innovation in Smartparks includes new ideas, actions and operations in order to reach: the optimization of the efficiency of processes; the reducing of consumption and use of natural resources; the use of supplies and materials; and the reduction and/or proper disposal of wastes. Smartparks require indicators that are appropriate for addressing sustainability from the perspective of Ecoinnovation and, today it was observed the insufficiency or even the absence of indicators in comprehensive scales that consider the planning and management of Smartparks, and incorporate the various relations of symbiosis and practical approaches and applied sustainability. Thus, the research has studied approaches and principles for Smartparks conception, as well models, criteria and frameworks of sustainable indicators, in order to define and to establish a Indicators framework for Smartparks application. The framework is composed by three categories representing stages of a Smart Park development (Planning, Monitoring and Management): “Infrastructure and services”; “Activities and Operation”; and “Interactions and symbiosis between institutions and Smartpark”. Twenty one aspects of these categories detail and help to guide the development of a set of indicators for Eco-innovation in Smartparks. It is expected that these results support the improvement and implementation of specific indicators systems for parks with industrial, agricultural and urban symbiosis, providing scientific basis for future researches on Eco-innovation and SmartParks.

**Keywords:** *indicators, Smartparks, Ecoindustrial Parks, Eco-innovation, Symbiosis*

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## 1. Introduction

Indicators are usually pointed out as a relevant tool to communicate complex information in a simplified manner. They are considered to be effective tools in monitoring, evaluating and communicating complex phenomena, making the concept of sustainable development operational, increasing transparency and accountability with the provision of widespread access to information, engaging stakeholders and supporting decision making (MASCARENHAS et al., 2010).

Indicators are useful instruments in many applications. Relevant and valuable studies of indicators have been conducted, providing important results for further indicators researches. Some studies have been dedicated to the development of tools and methods for establishing criteria and indicators applications.

Although several authors have formulated criteria or characteristics for desirable indicators, few studies have dealt with the process for the selection of indicators (LUNDIN and MORRISON, 2002).

This research focuses on the development and definition of indicators framework to contribute for addressing sustainability from the perspective of Ecoinnovation in Smartparks.

The study is inserted in project named "Eco-innovation in Smartparks", that is sponsored by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, a Brazilian Institution for Research support and financial funds) and by Spanish Ministry.

The main objective of this project is to develop and to apply (in an innovative, integrated and significant way, with an improvement of production processes, beholding social, economic and environmental settings) new approaches of conceiving planning and territorial management, aiming to reach sustainability management in parks for integrated symbiosis on industrial, urban and agricultural fields. This project comprises a team of around 50 researchers, teachers, and post graduated students of Spain and Brazil universities.

This project was designed to promote eco-innovation in smartparks, that, in summary, can be understood as a evolution of eco-industrial park concept through the development of a framework to implementation based on Brazilian and Spanish experiences. The approach of this project has configured the need to define and to propose specific indicators for management in this context.

The concept of SmartPark is still not consolidated in the literature. Nolt (2005) indicates that Smart Parks emerged as a proposal for a model that integrates sustainable production, agriculture and recycling technologies (Sustainable Manufacturing, Agricultural and Recycling Technologies). This integrated development model includes the sharing of power, water and even services and knowledge in order to optimize efficiency, reduce the use of increasingly expensive resources, achieving standards of low or zero emissions, and improve social contexts, economic and environmental. Kazemsky and Winters (1999) consider a Smart Park as an innovative model designed to integrate the inputs and outputs of water, energy and flows of various organizations and sustainable materials synergistically. It focuses on improving the collaboration of business practices between companies, communities and organizations to achieve more efficient operations and systematic approaches to cost reduction, pollution prevention opportunities and to develop new products, processes and management methods optimized for the Eco-innovation.

Along with the entire structure of an EIP (Eco Industrial Parks) and Smart City, the Smart Parks emerge as a similar model, but its focus is on the use of information and communication technology as a support for all management systems that involve a EIP. Moreover, its area of coverage beyond the limits of an EIP, whereas, in the industrial environment, urban space as an opportunity to symbiotic exchanges.

Smartparks require indicators that are appropriate for addressing sustainability from the perspective of Ecoinnovation. Today there are already targeted approach to sustainability in production processes indicators. However, it was observed the insufficiency or even the absence of indicators in comprehensive scales that consider the planning and management of Smartparks, and incorporate the various relations of symbiosis and practical approaches and applied sustainability.

So, there is a need to bridge the gap between the indicators already developed for the scale of production processes and indicators of the relationship of symbiosis, eco-innovation and sustainability in environmental planning and management in Smartparks.

The approach of this project has configured the need to define Smartparks principles and to propose specific indicators framework for planning and management in this context.

## 2. Methodology

The following steps in “ Fig. 1” describe the actions taken to develop a set of indicators for Eco-innovation in Smartparks.

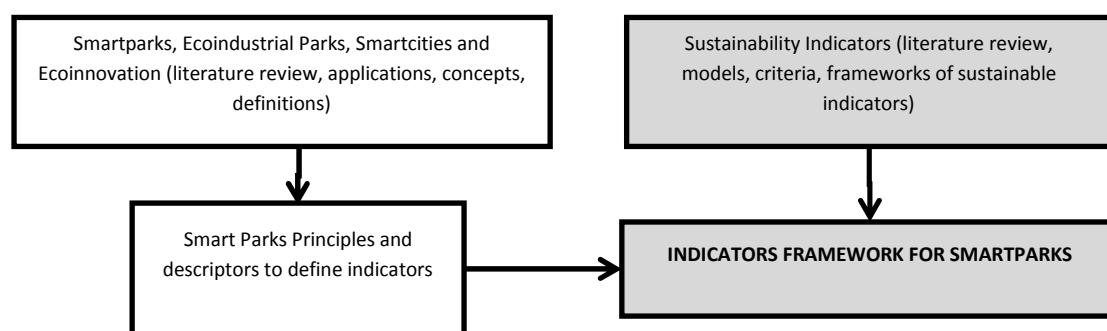


Fig. 1. Methodology

### 2.1. Smartparks, Ecoindustrial Parks, Smartcities and Ecoinnovation (literature review, applications, concepts, definitions)

A three stages methodology was developed to define eco-innovation and smartpark. First, a systematic literature review was conducted based on the systematic literature review (CONFORTO, AMARAL and SILVA, 2011). This stage aims to construct the corpus of definition for eco-innovation and smartpark. Second, definitions of eco-innovation and smartpark were proposed through a group-dynamic with specialist from several areas (Chemical Engineering, Geography, Environmental Sciences, Civil Engineering, Production Engineering, and Environmental Sciences and Technology Institute). Finally, a manual semantic analysis was conducted in order to define the terms. In this stage, the Semantic of Frames technique was used

For eco-innovation, 21 definitions were founded in systematic literature review and werer used into manual semantic analysis (including also four definitions from group dynamics). For Smart Park, 2 definitions were founded in systematic literature review and werer used into manual semantic analysis (including also four definitions from group dynamics). For the semantic analysis, the theory of construct frames was used. According this theory, the meaning of a specific word can be described through a semantic framework, in other words, a set of related concepts that represent a global standard of the knowledge of common sense.

After group dynamics and manual semantic analysis, the proposal of definitions was conducted based on a qualitative analysis, which consider the absolute quantity of each frame (entity, event, trigger, degree, purpose and circumstance).

We are considering the approach developed about Smart Park and Eco-Innovation as the following definitions:

Smart Park is a space, not necessarily with defined territory, formed by industries, organizations, businesses and services integrated by collaborative and sustainable manner, sharing knowledge, services, energy, materials and water through monitoring and automatic control based on information and communication technology seeking social, economic and environmental performance in order to achieve greater local and regional systemic efficiency in the urban, agricultural and industrial context.

Eco-innovation can be understood as the creation, development, assimilation, and dissemination of new or significantly improved business processes, products, technologies, business model and institutional structures in a competitive way, which are developed by firms and industrial parks, governments or non-profit organizations aiming to improve eco-efficiency (reduce costs and improve environmental performance) in order to satisfy human needs and provide a better quality of life for everyone.

## 2.2. Concepts and Approaches of indicators

It is not considered as an indicator a simple measurement of a parameter (value), but the information that comes from the significance of this measurement, enabling therefore assess the situation and trends of the environment (in the case of environmental indicator).

Indicators identify the relevant characteristics of a system and clarify the complex relationships between different variables involved in a particular phenomenon, making it visible or noticeable in order to communicate its contained information, as well as to verify the desirable situations achievement and to identify the trends throughout time.

An indicator is a statistic or parameter that, tracked over time, provides information on trends in the condition of a phenomenon and has significance extending beyond that associated with the properties of the statistic itself (OECD, 1994).

Gallopín (1997) expose that an indicator is a variable, which is an operational representation of an attribute (feature, system property), and transmits a information of condition variable and/or trend attribute. According to the author, the variable indicates the attribute, not being the attribute itself, but the image attribute (specific measurement or observation process).

Indicators are usually pointed out as a privileged vehicle to communicate complex information in a simplified manner. They are considered to be effective tools in monitoring, evaluating and communicating complex phenomena, making the concept of sustainable development operational, increasing transparency and accountability with the provision of widespread access to information, engaging stakeholders and supporting decision making (Mascarenhas et al., 2010).

Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems.

Scientists and practitioners agree that indicators have little chance of being accepted and used for decision making unless they may prove certain qualities defined and measured against operationalized criteria. Thus, the indicator developers postulate that the indicators should

be relevant, scientifically (conceptually, methodologically, etc.) sound, feasible, effective, pragmatic, accessible, understandable, etc. However, they do not propose a procedure or guidelines for validation of indicators (Bockstaller and Girardin, 2003). They usually define some criteria and try to apply them intuitively (Hak et al., 2012).

2.3. Stablishment of Smartparks Principles

Selecting SmartParks indicators must follow specific principles which characterizes the activities, the operation and the management of a SmartPark. So we proceeded to study and to gather these principles into the context of the Smartpark conception (See "Fig. 2.").

These principles were developed from the definition of SmartPark (semantic analysis), from stablish strategies and practices applied in EIPs, from the design and development of SmartCities, and from sustainability considerations.

PRINCIPLES FOR SMARTPARKS CONCEPTION	
<p><b>PRINCIPLE 1</b> COLLABORATION - COOPERATION</p> <p>Collaboration and cooperation between companies and between Smartpark and surrounding region on the exchange of energy, resources, common materials buying, water and usable by-products, recovered materials, wastes, energy. Link, network, mix or cluster of companies with generators, suppliers and customers at market-driven actions. Trust, commitment and proximity between companies, communities</p>	<p><b>PRINCIPLE 2</b> SHARING - COLLECTIVE USE</p> <p>Sharing and collective use of infrastructures and equipments, support services and facilities (training center, office for purchasing common supplies, transportation logistics office). Sharing and collective use of resources and materials. Sharing and collective use of technologies and environmental data and informations. Joint use of firm functions and sharing network construction</p>
<p><b>PRINCIPLE 3</b> SINERGIES – SYMBIOSIS - INTERACTIONS</p> <p>Strong synergies, symbiosis, interactions and linkage to surrounding communities through economic development, social and environmental programs</p>	<p><b>PRINCIPLE 4</b> INNOVATION – TECHNOLOGY AUTOMATED SYSTEMS</p> <p>Automated systems, infrastructures, equipments and sensors linked to computers to monitor and to control efficiency on water, waste disposal, energy generation, services, transports, access, security. Innovated product designs and new technologies on production</p>
<p><b>PRINCIPLE 5</b> EFFICIENCY – OPTIMIZATION – HIGH PERFORMANCE</p> <p>High performance of efficiency in use and reuse of resources (materials, water, energy). Redesign processes to reduce energy, materials, resources and water usage. Generation and use of renewable energy and maximize high level of energy efficiency through facilities, equipments designs (co-generation, cascading, connections, inter-plant energy flows). Optimize the production process with resource exchanges, reuse and recycling networks (highly effective regional by-product exchange, market of materials, waste management, resource recovery systems, recycling and remanufacturing)</p>	<p><b>PRINCIPLE 6</b> CLEANER PRODUCTION – ENVIRONMENTAL PERFORMANCE</p> <p>Emphasize cleaner production, improve the environmental performance and pollution prevention. Use of durable materials. Minimize waste generation, reduction of total waste stream (residential, commercial, public, and industrial). Define potential wastes products markets. Design collective gathering, integrated treatment plant and processing facilities of wastes. Avoid, substitution and reduce of toxic materials and hazardous substances (strict control of emissions, separation of by-product, residual materials) and reducing the quantity and toxicity of all emissions and wastes</p>
<p><b>PRINCIPLE 7</b> LOGÍSTICS - INTEGRATION</p>	<p><b>PRINCIPLE 8</b> QUALITY OF LIFE – HUMAN HEALTH – LOCAL DEVELOPMENT</p>

Integrated logistics engineering and management (products, materials and people transportation, designing routes, processes, infrastructures, equipments, public utilities with useful effects)	Enhancement of quality of life, human health and economic development in neighboring communities (projects and programs involving industry, wellness programs, local government and community-based organizations). Increased occupant productivity/satisfaction
PRINCIPLE 9 SUSTAINABLE DESIGN – INTEGRATED PLANNING	PRINCIPLE 10 PARTICIPATION – COMMUNITY INVOLVEMENT
Sustainable Design and Integrated Planning for more adequate use of space (based on ecological carrying capacity, available resources, communities interests, regional development plan, renewal and restoration of natural systems for biodiversity)	Define the community interests and involve the community in the design and development of the Smartpark. Create training and education programs, events (workshops, conferences, dissemination), community business development, building of employee housing, and collaborative urban planning

Fig. 2. Principles for Smart Parks Conception

Based on the guiding principles of Smartparks, and on the established indicators structure, specific guidelines were designed to help and to define Smartpark indicators, called Descriptors. The Descriptors have been established for each aspect of SmartParks indicators framework in order to facilitate the selection and the development of indicators.

The definition of principles and description of aspects presents in the framework helped in a development of descriptors. The descriptors are key components for each aspect of the framework. The descriptors will be component of a set of guidelines for selection and developing indicators for Smart park.

*2.4. Development and Definition of Indicators Framework for Smartparks*

In this step, we use the Smart Park definition to develop a set of principles to guide the framework. A framework needs to be developed, or agreed upon, to be able to structure what is to be monitored, the interlinkages between the monitored aspects, and the identification of possible actions to influence the observed trends and developments.

The framework developed was based in Smart Park definition and inspired in Lowe, Moran and Holmes(1995), Lowe (2001) and Giffinifer et al. (2007). The reason for this choice was that the structure of an Eco-industrial Park(EIP) is very similar to Smart park and the idea of Smart City introduced by Giffinifer et al. (2007) helped to realize some categories and aspects.

**3. Frameworks for Eco-Industrial Parks and Smart Cities**

The conceptual framework is the starting point in constructing a system of indicators. The framework should clearly define the phenomenon to be measured and its sub-components and select individual indicators and weights that reflect their relative importance and the dimensions of the overall composite. The Conceptual frameworks help us to depict the concepts and dimensions we are concerned with, but they do not immediately provide us with a set of indicators. To develop these, we need to analyse the frameworks and identify within them the key dimensions for which indicators are needed.

According Lowe (2001) environmental performance is a combination of three elements. At the core of environmental performance is resource utilization within industrial processes. This element is concerned with the amount and type of resources used and consumed within a plant’s industrial process, (what goes on inside the fence). The second element, emissions from industrial processes, relates to emissions or releases from processes to the environment (what passes over the fence). The

third element, interactions of industrial processes and releases with natural system components, concerns the impacts of the industry on the natural environment. Environmental performance is a function of combined performance in these three elements. However, we need to break them down further to develop detailed objectives. The framework of Lowe (2001) helped to understand what should consider in the environmental dimension, mainly about the interactions element. According the authors, the environmental interactions the EIP considers the impacts of the industrial processes and their releases and emissions on the larger environment. These impacts include impacts on the natural ecosystem, wildlife, and wildlife habitat; interactions with neighbors, both other industries and area residents; and interactions with the physical setting-the land, air, and water. This Element of environmental performance is very much softer, (i.e., more subjective and value laden) than the other two elements, which are more readily identified.

The Smart City framework proposed by Giffinfer et al. (2007) identified six characteristics as a roof for the further elaboration of smart cities which should incorporate the findings. According this structure, to describe a smart city and its six characteristics it was necessary to develop a transparent and easy hierarchic structure, where each level is described by the results of the level below. Each characteristic is therefore defined by a number of factors. Furthermore each factor is described by a number of indicators. The factors were defined in several workshops always having the overall target, smart city development in mind. Finally 33 factors were chosen to describe the 6 characteristics. To analyze the performance in each factor 1-4 indicators were selected and assigned to each factor. For two factors, "Ability to transform" and "Political strategies & perspectives" it was not possible to receive sufficient data. Therefore 31 factors finally remained for the ranking. The six characteristics in this framework show more different elements when we talk about "Smart" concept. In specific "Smart Environment", the environmental protection and sustainable resource management are different elements, if compare with the EIPs Framework.

These existing frameworks were relevant to the topic or field because was defined important categories and dimensions in different scales (city and park) and in different levels of comprehensiveness.

#### **4. Conceptual Framework for Smartparks: Definition of principles, structure, categories and aspects**

We propose a framework to define the categories and aspects to be measured in a Smart Park through indicators. This framework will also enable the team of this project to develop others issues in these Parks.

This proposed framework following important characteristics<sup>1</sup>

- Logical in structure: the informations about Smart Park can be analysed and organised in a structured way;
- Relevant: the informations about Smart Park defined are important for the managers to develop a set of indicators;
- Comprehensive but concise;
- Cognisant of other frameworks: The framework of Lowe, Moran and Holmes(1995), Lowe (2001) and Giffinfer et al. (2007) was used as a inspiration to develop this framework;
- Coherent: The categories and aspects was developed using a definition and a set of principles for Smart Park.
- Understandable

<sup>1</sup>Characteristics of good practice taken from "Measuring Well-being: Frameworks for Australian Social Statistics. Australian Bureau of Statistics. Page 15".

This Framework is composed by three categories (“Infrastructure and services”, “Activities and Operation” and “Interactions and symbiosis”) and twenty one aspects (“Fig.3.”). Each category represents stages of a Smart Park development (Planning, Monitoring and Management).

The conceptual framework (“Fig. 4.” and “Fig. 5”) helped to guide the development of a set of indicators for Eco-innovation in Smartparks.

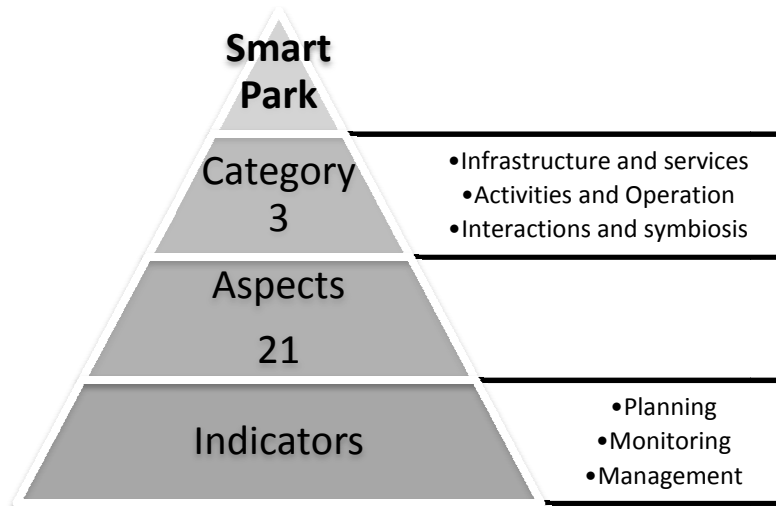


Fig. 3. Hierarchic structure for Smart Park' framework

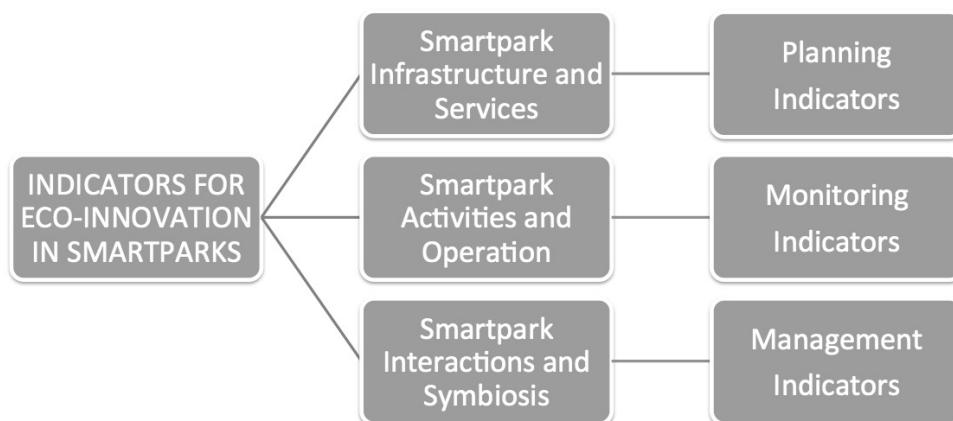


Fig. 4. Categories of Indicators Framework for Smart Park



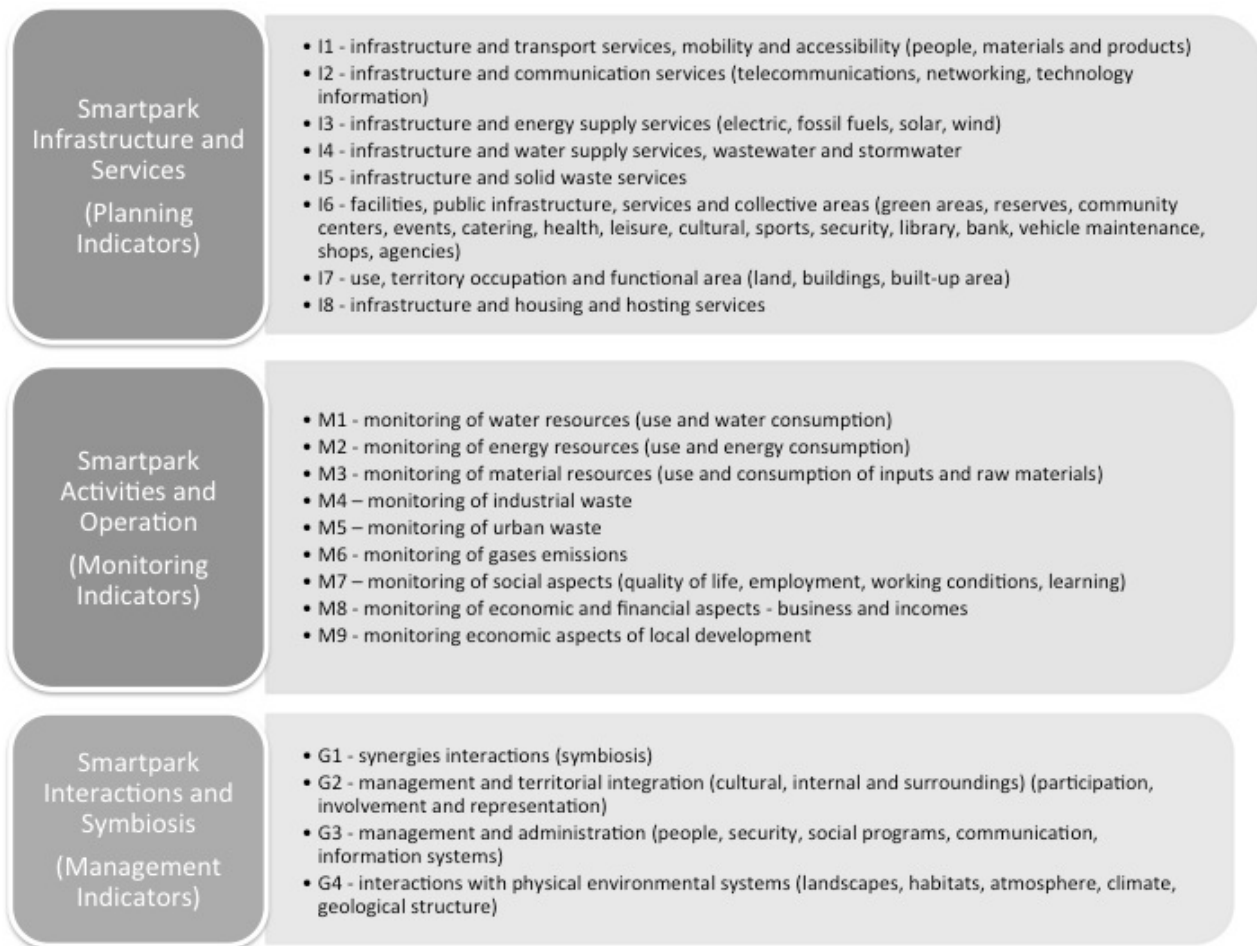


Fig.5. Indicators Framework for SmartPark

## 5. Conclusions

The construction of the principles from the SmartPark and eco-innovation definitions helped in the construction of the proposed framework. The principles present keywords that define the main idea of them: collaboration/cooperation, sharing/collective use, synergies/simbiosis, innovation/technology, efficiency/optimization, cleaner production/environmental performance, logistics/integration, quality of life/human health, sustainable design/integrated planning, participation/community involvement.

About the framework, for each aspect should be selected indicators to characterize the subjects addressed. These results support the improvement and implementation of specific indicator systems for parks with industrial, agricultural and urban symbiosis, providing scientific basis for future researches on Eco-innovation and SmartParks.

For definition of the indicators, there was the need to establish future steps for the development of Key-Indicators for SmartParks, suggesting the following actions:

- The definition of the indicator profile, containing the descriptive characteristics, operational procedures, data indicators, analysis and interpretation of the results;
- The establish of indicators criteria, defining methodological procedures to select indicators in a participatory way;
- The possibility to set a SmartPark Index, considering the principles and strategies previously established;

- The possibility of to define and to analyze indicators for every aspect of indicators framework of Smartpark.

## 6. Acknowledgement

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