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Industrial Ecology and the Building of Territorial Knowledge: DEPART, a French Research Action Program Implemented in Harbor Territories

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Abstract

Industrial ecology explores the analogical relationships between biological ecosystems and anthropogenic systems, in order to optimize the latter's resource management inspired by the former's mechanisms. A renewed conception of industrial ecology consists in considering it as the building process of a collective territorial knowledge, in its two complementary dimensions: the development of a collective knowledge and the development of the collective through knowledge. It proposes a collaborative construction of a territorial definition, through the sharing and mutualization of information flow, transmitted by the territory and interpreted by actors, leading to a collective decision process.

Industrial ecology; Territorial intelligence; Collective intelligence; Information

1. Introduction

1.1. Territories as ecosystems

By exploring the potential of theoretical and operational innovations of the analogical relationships between biological ecosystems and anthropogenic systems, industrial ecology aims at accompanying industrial systems, from a juvenile expansion, characterized by the exponential increase of environmental resources consumption and its poor exploitation leading to waste production, to a mature development, characterized by the optimization of resources consumption and reduction of waste production through the

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densification of its network [1]. This pattern of relationships is to be developed between various industrial activities as well as with the environment, understood through its ecological, spatial and temporal dimensions. While a technological approach of industrial ecology, focusing on by-product exchanges, seems to become dominant, it appears worth to remind that the core idea of industrial ecology is to reinstate anthropogenic systems within the biosphere, and to (re)place local industrial activities within the territorial system [2].

This territorial approach of industrial ecology is embedded in a renewed geographical definition of territories. By analogy with biological ecosystems, a territory can be defined through various functional units, resulting from actions of organisms, or groups of organisms, using one or several resources locally available. Transposed into anthropogenic systems, this means that a relevant definition of the territorial system must reckon multiple facets: the system of the geographical space appropriated by man, but also the system of representations of this geographic space by the different territorial actors and the system of actors interrelated and having a conscious or unconscious action on the geographic space [3]. For instance, harbor territories can assume multiple realities depending on how local actors define the functional unit of their territory through their perception and action: if this functional unit focuses on the maritime industry and the exploitation of sea resources, the harbor perimeter will follow the whole maritime logistic chain; if it focuses on the port authority skills and the land management, the harbor area will correspond to its regulatory or administrative boundaries.

This point of view echoes the realist constructivism which argues that a geographic territory cannot be understood as a reality independent from actors that observe it, think it, and shape it. Spatial objects become geographic objects through a social process of objectification. The coproduction of geographic objects can thus be understood as a dialogue between different processes of objectification [4]. Closely interconnected with the flows of local natural resources and manufactured goods, the flow of information contributes to this collective process of territorial definition, enabling the dialogue between actors' multiple representations of their territory. Information flow thus contributes to build the link between territories and stakeholders' perceptions and actions by participating to the co-construction of a shared definition of territorial functions. This collective territorial knowledge development is the first step of a collective decision process, as the very defining words that represent the territorial reality define the framework for decision and action [5]. Thus, the co-construction of territorial definitions implies the co-construction of shared issues justifying collective action (Figure 1).

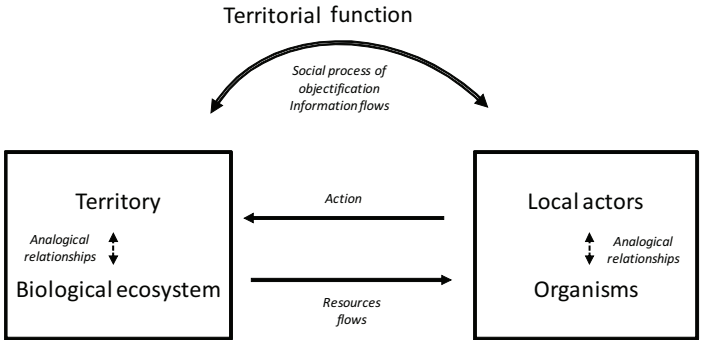

Figure 1 – Territorial dimension of industrial ecology

Industrial ecology, understood as "territorial ecology", finds its foundations in this collective process of territorial definition. Based on the analogy with the definition of biological ecosystems, it proposes a collective construction of a territorial definition, through the sharing and mutualization of information flow, transmitted by the territory and interpreted by actors, leading to a collective decision process. It appears that industrial ecology must be understood as the building process of a collective territorial knowledge, in its two complementary dimensions: the development of a collective knowledge and the development of the collective through knowledge.

1.2. Industrial ecology as a process of collective knowledge development

This innovative approach of industrial ecology focuses on the management of information, understood as the way an individual perceives an existing data within a system, which is observed through a reference framework. Relevant knowledge to the decision-making process is indeed updated through interaction with the environment in an iterative process. By reinstating the anthropogenic system within the biosphere, industrial ecology thus participates to rebuild a continuum between the environment and human society, between the territorial system and the system of actors. Mimicking the stimuli/response process of biological systems, anthropogenic systems have to improve their awareness to territorial stimuli (signal) and have to develop a collective knowledge process allowing converting these data, into information, then into knowledge, in order to feed a decision-making process coherent with the territorial system's issues (Figure 2).

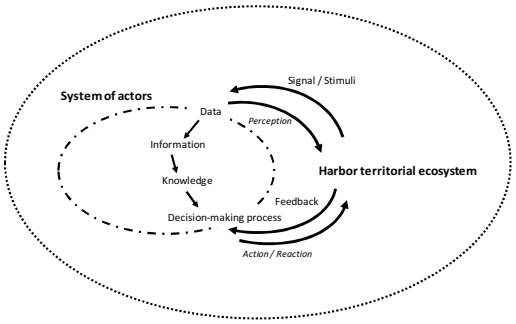

Figure 2 – Industrial ecology as a collective knowledge process (adapted from caENTI report [6])

The integration of the collective knowledge process in industrial ecology implies a cardinal turn for environmental management. The mainstream comprehension of environmental issues based on the protection of environmental compartments and the reduction of anthropogenic impacts is embedded in the deeply funded assumption that biological systems and anthropogenic systems are partitioned and that the only link existing between them is the negative impact that human activities have on biosphere. Environment is considered as an alien reality. Downstream, the collection of data thus focuses on the quantity and quality of these impacting flows and the capacity of the environment to absorb them. The collective knowledge process developed by this innovative approach of industrial ecology lays down a continuum between biological systems and anthropogenic systems, reinstating the latter within the former and developing the relationships between these two dimensions of the same biosphere. This interaction between environment and human activities constitutes the territory as defined previously. Upstream, the collection of data thus focuses on signals coming from the environment that can result in coherent reactions of human activities.

1.3. The collection of data as a major issue for industrial ecology

These arguments contribute to restore the importance of data collection. Indeed, this major question seems often neglected and even ignored. Industrial ecologists highlight regular difficulties to collect valid and relevant data, some of these issues appear more like a fatality they have to cope with than a major scientific bolt they have to unlock. Yet, the methodology for collecting data and converting them into information and collective knowledge appears as essential for the development and implementation of industrial ecology. By (re)building and (re)inventing the interface between the territorial ecosystem and the system of actors, the methodology builds the framework on which are rooted the understanding of main issues and the guidelines for actions.

DEPART "From waste management to circular economy, study of the emergence of new dynamic partnerships" (2010-2012) is a French research action program for the implementation of industrial ecology, which challenges this major scientific bolt. It questions the potential of developing diagnosis and

analysis tools in order to collect relevant data which grasp the actors' perceptions of the territorial ecosystem. This approach can be combined in order to produce information and initiate a process of collective knowledge contributing to the decision-making process. Thus, it explores hypothesis borrowed to the field of territorial intelligence: to what extent does the organization of collective knowledge by a system of actors, within a territorial framework, facilitates collaborations for a global optimization of resource management, and especially waste management?

2. Toward the production of a territorial information system

2.1. Collective knowledge creation process for industrial ecology

Collection of data and their conversion into information and knowledge raise different methodological issues: i) how to collect raw data through the observation of actors' perceptions of their territories? ii) how to convert these observations from raw data to information and collective knowledge? iii) how to impulse cooperation around the co-production of territorial data, from the "production of data on my own" for individual action, to the "collective production of data" for collective action [4]? Aware of these methodological issues, the DEPART project mobilizes multidisciplinary approaches and methods to transform these brakes into methodological objectives (Figure 3).

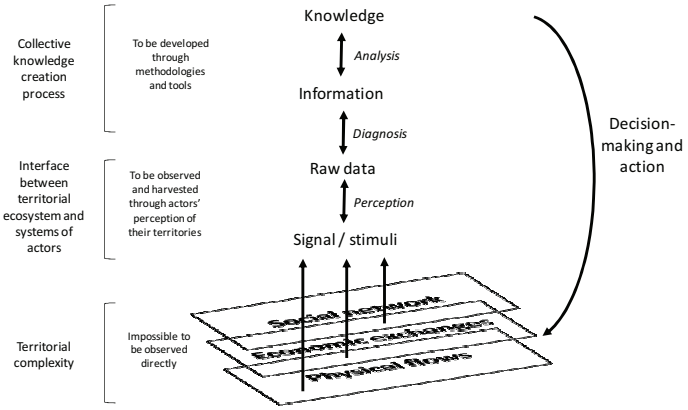

Figure 3 - Production of a territorial information system

At first stage, it aims at studying the multiple sources of data that can be at the interface between the territorial ecosystem and the system of actors, then at optimizing data collection. This blurred interface is approached by harvesting the territorial stakeholders' perception of the territorial complexity and integrating multi-sources data and multi-sets of topics. The challenge of this objective is to aggregate these multiple individual and collective representations of the territorial complexity, without reducing their diversity, in order to draw close a shared definition of the territorial system.

At a second stage, it aims at developing methodologies and tools in order to process information and knowledge from these raw data and build a system of information that can guide the collective decision-making process. The purpose is to produce synthesized information participating to the creation of a collective knowledge, in an adapted and relevant form in direction of various targets (political decision makers, port authorities, associations, etc.)

The following paragraphs detail methodologies and tools developed in order to optimize both the collection of raw data through territorial stakeholders' perception and the production of information and collective knowledge nourishing the collective decision-making process. For a purpose of clarity of the presentation, these methodologies and tools are presented successively, even though the reader will notice that they are deeply interconnected. Focusing on an industrial ecology approach of by-product valorization and mutualization of waste equipments, these methodologies and tools have been

implemented to specific waste management issues in two major French harbor areas: for instance, dredged material and shipping wastes in the Port of Le Havre and the Port of Marseille.

2.2. Territorial analysis grid: building a shared definition of a territorial system on the basis of actors' perception

Challenging the postulate of a social objectification of territorial complexity, a territorial analysis grid has been developed in order to question, collect and study the various representations of harbor territories from a waste management point of view. At the core of the territorial analysis methodology, a list of waste management issues has been elaborated through an iterative process: based on an existing literature review performed by Boutaud [7] as well as on various experiences of implementation of sustainable development, and industrial ecology in particular, in harbor areas, this list has been shared with different harbor stakeholders (political decision makers, port authorities representants, associations representatives, etc.) in order to assess the relevance of the defined issues for different perceptions.

The methodological process consists in performing interviews with various local stakeholders, in order to harvest their own perception and representation about these waste management issues on their harbor territory. The first part of the interview is dedicated to analyzing the actor's reference system which contributes to the perception and representation he delivers. These key factors (professional function, area of concern, legitimacy, etc.) are fundamental to allow a relevant cross analysis of the different territorial representation profiles. The second part of the interview consists in assessing the local actor's importance system (which waste management issue is more important than the others? At what range?) and valuation system (for each waste management issue, how do you assess the territorial political and operational response to the problem raised?). Through an aggregate operation, the result draws the local actor's territorial representation profile: through a specific reference system framework, this territorial profile expresses the major waste management issues and objectives for the harbor territory. Multiplying interviews harvesting numerous and various actors' territorial representations, the challenge is to aggregate them into one shared territorial representation profile able to express unity and diversity, coherence and incoherence.

Table 1 - Territorial analysis methodologies and tools contributing to the collective knowledge creation process

Collective knowledge creation process	**Methodologies**	**Tools**
Signal/Stimuli		
↓↑	Collection of actors' territorial	Interview on the basis of a territorial
Raw data	representations on harbor waste	analysis grid
↓↑	management issues	
Information	Analysis of one actor's territorial	
↓↑	representation profile	Individual territorial representation profile
Collective knowledge	Aggregated analysis of numerous and	
↓↑	various actors' territorial representations	
Collective decision-making process	profiles (inventory and objectives)	Collective territorial representation profile

As part of the process of collective knowledge creation defining this innovative industrial ecology approach, the territorial analysis methodologies and tools contribute to harvest the local stakeholders' perceptions and interpretations of the territorial system's signal, to analyze these raw data in order to convert them into information and to contribute at building a brick of the collective territorial knowledge through a shared territorial definition (Table 1).

This shared territorial definition is of major interest for the implementation of industrial ecology in harbor territories: enabling to understand different perceptions of waste management issues, it allows adapting the process of acculturation to industrial ecology to the existing cultural schemes and

frameworks. Taking a photo of the perceived territorial context in terms of waste management, it allows positioning industrial ecology in support of the main limits encountered by the territory, or, on the contrary, on the support of the main drivers promoting the territorial development.

2.3. Skill ecosystem's analysis: collecting relevant data for industrial ecology

The optimization of the collection of useful data for industrial ecology is one of the main challenges of the DEPART project. Indeed, applying the analogy with biological ecosystem to the management of information, this innovative approach of industrial ecology aims at accompanying anthropogenic systems to optimize the consumption of labor energy required for the harvest of data and to reduce the "information waste" (which can be understood as the data and their analysis in terms of information that appear to be useless for the implementation of industrial ecology).

The optimization of data collection and information production for industrial ecology shall be reached through an iterative process, enabling to focus progressively on the relevant types of data, on the basis of experiences and feedback. As such, the methodology developed for the skill ecosystem's analysis takes its roots in this challenge: industrial ecology experiences led in France (and capitalized through formalized methodologies and interviews) allows focusing on the locally available skills as one of the most relevant economic data.

The collection of skills' data, thanks to existing governmental data basis (inter alia), are converted into information through the construction of an ecosystem of local skills: nourished by material, substance and energy flows as well as immaterial flows such as data and information, this ecosystem of local skills is composed of clusters, research centers as well as socioeconomic stakeholders, with the support of national and regional local authorities (Table 2). The articulation of these local skills constitutes a lever for the implementation of industrial ecology.

Table 2 – Skill analysis methodologies and tools contributing to the collective knowledge creation process

Collective knowledge creation process	**Methodologies**	**Tools**
Signal/Stimuli ↓↑ Raw data ↓↑ Information ↓↑ Collective knowledge ↓↑ Collective decision-making process	Collection of local available skills through existing data basis Analysis of these skills through a systemic approach and identification of major lever skills for industrial ecology	Data basis Skills ecosystem tool

As part of the collective knowledge creation process at the core of this innovative approach of industrial ecology, the skill analysis methodologies and tools aim at optimizing the collect of relevant data and at analyzing them through a systemic approach. This interdependent local skills analysis constitutes a lever for the implementation of industrial ecology. It helps identifying anchor actors able to flow into the decision-making process and to unlock strategic, methodological or operational bolts.

2.4. Social network analysis: building a shared representation of local actors' relationships

At the confluence of the two previous methodological guidelines, the social network analysis is embedded into the social objectification process of territorial complexity as well as into the need to optimize the collection of relevant data. Indeed, it studies the potential of information and collective knowledge creation of two sources of raw data: on the one hand, the local actors' representation of the social relationships networking the territorial complexity; on the other hand, the available data (data basis,

analysis of workshops' composition, etc.) able to complete the representation of the social networks (Table 3).

Table 3 – Social network analysis methodologies and tools contributing to the collective knowledge creation process

Collective knowledge creation process	**Methodologies**	**Tools**
Signal/Stimuli ↓↑ Raw data ↓↑ Information ↓↑ Collective knowledge ↓↑ Collective decision-making process	Collection of actors' representations of the social network Analysis of these various representations through a social analysis software Comparison and sharing of this various representations of the social network	Data basis, interviews Social network analysis software

These developments participate to existing studies on the contribution of social network analysis in industrial ecology [8], from description to recommendation. Indeed, these methodologies and tools highlight another side of the definition of territorial complexity: while the territorial analysis grid focuses on a collective definition of territorial waste management issues, the social network analysis adds another layer (the social relationships related to waste management issues) that contributes to go deeper into the local actors' perceptions of the territorial complexity. As such, the social network analysis participates to the collective knowledge creation process essential for the territorial development of industrial ecology. In concrete terms, this analysis enables to build the governance of industrial ecology, taking its roots in the existing social network and/or exploring the different scenarii of creation of new social relationships dedicated to the optimization of resource management as well as their consequences on the whole territorial social network.

2.5. Flows analysis: building a community of practice

While industrial ecologists strive to perform an exhaustive material and energy flows analysis (MFA), this approach of industrial ecology, based on the social objectification process of territorial complexity, and thus, of the social building of resource management major issues, proposes to reverse the question: instead of asking what are the available flows, it addresses what are the perceived needs and expectations shared by local actors [11]. The DEPART project builds its flow analysis methodologies and tools on the basis of a shared definition of problematic flows for harbor territories (for instance, dredged materials, construction/deconstruction wastes and shipping wastes).

In order to collect data relative to these specific flows, this approach proposes to initiate a process of co-production of data and of collective building of MFA, through the development of a common culture of geographic information. It is no longer an issue of exchanging and diffusing data and information through a spatial data infrastructure than an approach of co-construction of new territorial representations thanks to the building of a community of practice [4]. Geographic Information Systems (GIS) are thus developed in order to gather existing data relative to harbor specific flows, and co-construct, on this basis, a culture of sharing, assessment and updating of these data among local stakeholders. Confidential issues are partly by-passed as the implication of each local actor in this coproduction of data is embedded in its own reference system guiding him in the selection of data and information he gains sharing (Table 4).

Table 4 – Flows analysis methodologies and tools contributing to the collective knowledge creation process

Collective knowledge creation process	Methodologies	Tools
Signal/Stimuli	Shared definition of waste management	Workshop
↓↑	issues on harbor territories and collection	
Raw data	of data through data basis and interviews	
↓↑	Organization of these data thanks to a GIS	GIS
Information	Building of a common culture of	
↓↑	geographic information and co-production	Development of specific queries
Collective knowledge	of information	
↓↑	Identification of shared opportunities of	
Collective decision-making process	synergies	

This approach challenge cooperation around the co-production of territorial data, from the "production of data on my own" for individual action to the "collective production of data" for collective action [4]. Opportunities of synergies (material flows exchanges, mutualization of equipments, collective governance, etc.) performed by this flow analysis approach thus correspond to the local actors' perceptions and representations of what is feasible and what is coherent with the territorial development.

3. Discussion and conclusion

This research work constitutes a first step in developing this approach of industrial ecology. Based on a collaborative knowledge creation process, it aims at building the first stage of a collective decision-making process based on a shared representation of the territorial complexity. Further developments of this approach are needed.

For the implementation of industrial ecology in harbor territories, a research perspective is to root the development of methodologies and tools instrumenting this collective knowledge process into a renewed governance of information in territories. Industrial ecology will thus learn a lot from a connection with economic intelligence, and more precisely, territorial intelligence [9]. Territorial intelligence can be considered as a strategic principle aiming at optimizing the territorial competitivity by the management of information. It can result in the creation of a system interconnecting different stakeholders to thin the circulation of information [10,12]. Thus, as long as industrial ecology is concerned, the cooperation around the production of territorial data, information and knowledge must give birth to a dedicated cell of territorial intelligence able to mutualize data collection and the production of information. It allows to nourish collective knowledge and thus to inform the collective decision-making process and to contribute to the optimization of territorial resource management (Figure 4).

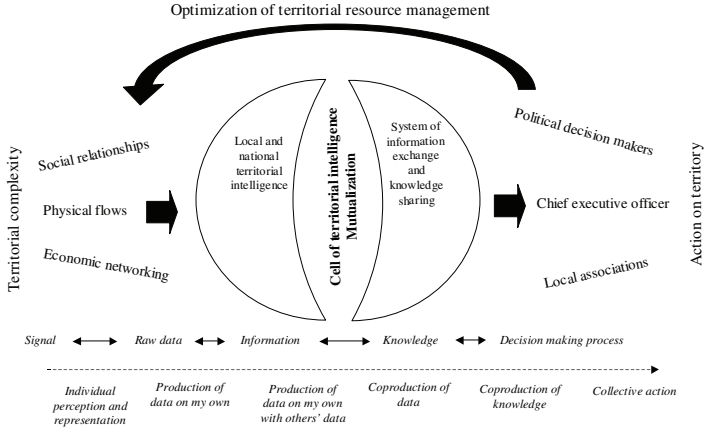

Figure 4 – A territorial information system for industrial ecology (adapted from Junqua and Moine [9])

Further development of this research issue can also be found in the boundaries enlargement of this collective knowledge creation process. Hitherto, these research works has been developed into local or regional perimeters. The challenge is to enlarge this approach to international scale by interconnecting different harbor stakeholders over the world around a same objective of producing collective knowledge contributing to the optimization of resource management in these specific areas. A research project is on going in order to collect international feedback of industrial ecology implemented in harbor areas and to engage a first step toward the constitution of a harbor industrial ecology network.

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