Governing Sustainability in Urban Ecosystems: Arguments for a Transdisciplinary Framework

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Abstract

This paper points toward the need for transdisciplinary frameworks for understanding the nature and challenges of urban sustainability. It questions the conventional, anthropocentric approaches to sustainability, particularly their neglect to articulate the complex and material dimensions of sustainable endeavors. Anthropocentric sustainability is a controversial idea. It prevents us from being able to develop a sound analysis of ecological threats, and, therefore, it prevents us from elaborating effective proposals for sustainability and sustainable development. We need to step away from any conception of "the natural" as Nature. The meaning of "natural" is associated with sustainability, both in urban and non-urban contexts. Thus, we suggest that "ecology" and "nature" are concepts in opposition, and we elaborate a working definition of sustainability that is relevant for a situation of rapid urbanization in the Anthropocene. Accordingly, as discussed elsewhere (del Cerro Santamaría, Del Cerro Santamaría, G. (2019a). Megaprojects, Sustainability and Competitiveness in the United Arab Emirates, Unpublished Fulbright Scholar Project Proposal, New York City.), an urban context will be defined as sustainable "if it is planned and governed to account for the capacity, fitness, resilience, diversity and balance of its ecosystem. We take the view of sustainability as an organic process including environment, economy and community: form and efficiency (environmental factors in design, architecture, engineering and construction) as well as policy (urban plans and practices that explicitly aim at maintaining and improving the social and economic well-being of citizens)." We first explore the environmental challenges in a rapidly developing country (China), and we then assess the potentialities of innovation districts in the fostering of urban sustainability. After this analysis of empirical referents, we lay out the elements for a transdisciplinary framework that can guide the governance of sustainability in urban ecosystems.

Keywords

Sustainability • Rapid urbanization • Transdisciplinarity • Ecology • Governance • Complexity • Innodistricts

1 Introduction

The concept of urban sustainability can first be found in a 1968 publication by Stanley A. Cain with the title "The importance of ecological studies as a basis for land-use planning." This piece shows how ecological studies contribute to planning and how land use and planning become tools for urban sustainable development (Zhang & Li, 2018). On the other hand, Vojnovic (2014) proposes to consider society, economy, and environment as the basic elements of any conception of sustainability. These elements

> can be equally promoted through the concepts of inter-generational and intra-generational equity. The first is concerned with maintaining the quality of natural ecological systems and their services over time, while the second is based on promoting the equitable access to resources within current generations, providing human populations with basic needs (2014, 36).

From the viewpoint of Hannan and Sutherland (2015), we can see six principles that can be used as elements in the evaluation of urban sustainability and how urban ecosystems contribute to it. These elements include:

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(a) create of a place with a vibrant culture, where a diversity of social, environmental, and economic activities can take place,
(b) ensure social justice and contribute to intra-generational and inter-generational equity including the recognition of social, environmental and cultural heritage,
(c) ensure adequate community participation and democratic overnance,
(d) ensure urban spatial integration and promote more sustainable and efficient forms of transport,
(e) promote economic growth and employment creation and ensure economic viability, and
(f) minimize pollution and waste; maximize energy efficiency and maintain ecological integrity (Hannan & Sutherland, 2015, 41).

In this context, planning is instrumental for sustainability in the various contexts where it develops. However, the implications of all of the new sustainability dynamics for the livability of city regions have not found their way in generating new regional planning approaches. Instead,

> governments adjust plans to accommodate private sector plans on an *ad hoc* project-by-project basis. While this can be seen as being realistic in the face of formidable processes of globalization and neoliberal governance, the greatly increased stress on the urban environment suggests the need for more proactive responses to environmental deterioration and flooding (Douglass, 2010, 18).

In lieu of integrated planning, various levels of government in many metropolitan regions around the world

> are moving forward with more targeted responses such as disaster preparedness, river cleanups and improvements in water control infrastructure. The outstanding question is whether such sector projects and programs sum up to a coherent strategy that can effectively address the portent of rising human costs of environmental damage (Douglass, 2010, 21).

If we take, for example, the case of urban megaprojects, any sustainable strategy needs to look beyond the "iron triangle" of fulfilled schedule, budget, and specifications in analyzing megaprojects.

> Big projects need to be judged for how they meet objectives over time, amid shifting societal, political, and environmental values. Measuring the success of a mega-project is not linear. There are twists and turns not only in terms of engineering and the emergence of new technology, for example, but in the moving target of public expectations. New problems always crop up that such projects are expected to solve, long after the first blueprints were approved. The biggest plans tend get started under political leaders who are almost always gone by the time of completion (Omega Center, 2012, 26).

We know many aspects of rapid urbanization and how megaprojects contribute to it. This research area has been developing quickly in the past decades. However, we know little about how urban megaprojects are related to the practice of sustainability, and about the specific governance settings and arrangements that have the potential to advance sustainability goals.

Urban sustainability can be generally defined as the idea that "a city can be organized so that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). The goal of urban sustainability obeys a logic of multiple, intertwined factors, and that implementing and governing sustainability in urban ecosystems entails a shift in the conventional approaches to planning.

As shall be argued below, urban sustainability is a complex endeavor requiring a transdisciplinary sensitivity and framework in order to be approached and understood. We shall arrive at proposing some elements for such a framework by first exploring environmental challenges in a rapidly developing country (China), and then by assessing the potentialities of innovation districts in the fostering of urban sustainability.

2 Infrastructure and Environmental Challenges in China

China's socioeconomic development uses infrastructure and megaprojects as basic strategic elements. Positive results are clearly visible, but the country's goals regarding sustainable development have not been reached. According to the PRC Ministry of Ecology and Environment (PRCMEE),

> two-thirds of China's lakes have chemical deficiencies caused by pollution. As a result of pollution and increasing consumption, two-thirds of China's cities are short of potable water. Air is heavily polluted across the northern heavy industry belt from Shanxi to Liaoning provinces and along the heavily industrialized east coast. Many polluted industrial sites will require extensive soil remediation before they will again be fit for human use (PRCMEE, 2016, 13).

According to a New York Times report, China is responsible for 47% of the world's coal burning, which is more than all other countries in the world combined. As a result,

> respiratory diseases that are directly related to air pollution are currently the leading cause of death in China, according to the World Wildlife Fund (WWF). In addition to some of the world's worst air pollution, China also has many waterways that are highly polluted. According to the Economist, more than 50% of China's surface water is not fit for human consumption, whereas approximately 60% of the groundwater under Chinese cities is considered to be severely polluted (Watkins et al, 2018, B3).

2.1 Energy

According to the World Bank,

> Electricity production in China doubles nearly every 10 years. China now generates 18% of all electricity globally, only

> slightly less power than the United States. China's non-fossil fuel electrical power sources are still overwhelmingly nuclear and hydro (96% combined), according to the World Bank. The more difficult target to achieve will be 20% renewable power production by 2020. Despite rapid growth, wind and solar energy sources still make up <1% point of total electricity production in China. Since solar power is still more expensive to produce than electricity from coal-fired turbines, the government offers subsidies either for capital investment or operations, but neither subsidy is sufficient to break-even under current conditions (World Bank, 2018, 25).

In addition to renewable power generation, there is a growing market for energy service company (ESCO) projects,

> which can help to reduce energy consumption and greenhouse gas emissions. ESCO projects typically finance the purchase of new energy-efficient equipment through projected savings on future fuel bills in comparison with old or energy-hungry machinery. While the World Bank and many smaller "green funds" have already entered this market, many local investors are hesitant, since they find the five-to-ten year payback period too long. This is one factor contributing to opportunities for foreign energy savings companies with local partners (Bachman & Burnett, 2012, 35).

2.2 Water and Wastewater

Future efforts to increase water sector performance should adopt a more integrated approach.

> The different components of urban water systems—water, wastewater, and stormwater—are often handled by different government organizations with different, sometimes competing agendas. Integrated water resource management can be used to match water quality to water uses, improve treatment cost-effectiveness, and raise the quality of discharged water to environmentally safe levels. China's water industry will open up for reverse osmosis, membranes, and other advanced treatment technologies that minimize energy inputs and simplify operations (Southerland, 2017, 43).

2.3 Transportation

One of the keys in Chinese urban development is transit-oriented development (TOD). In this context, one sees that factors involving density are not usually included in design analysis. However,

> many cities retrofit their zoning codes after subway construction to allow development to cluster around transit stops. With the right land use mix, this offers the possibility of higher use of non-motorized transport. At least 13 Chinese cities currently have one or more subway lines under operation, 54 lines covering 1,700 km. Another 76 lines, or an additional 1,600 km, are under construction. The target is 40 subways systems by 2020 covering about 7,000 km. At this pace and scale, TOD is poised to make a big difference in the long-term sustainability of urban living (Luo et al, 2017, 41).

2.4 Desertification

According to Smith,

> China is also dealing with rampant soil erosion and desertification, which is a type of land degradation that is a result of previously fertile soil transforming into arid land due to poor agricultural practices and land management, as well as extreme climate change. According to the WWF, desertification has already swept over 30% of China's land mass. Since 1978, the Chinese has followed guidelines set by the Three-North Shelter Forest Program, otherwise known as the Great Green Wall, which involved the construction of what is now over 66 billion trees that are used to block the path of the Gobi's storms. Despite this afforestation project, the desert's expansion continues to affect various surrounding cities (Smith, 2018, 32).

And Schwärzel argues that,

> As towns continue to get swept under sand as a result of these storms, the Chinese government is forced to move affected populations away from degraded lands. In fact, between 2003 and 2008, over 650,000 people who were previously living in China's Inner Mongolia province were forced to resettle in other cities. An even more concerning fact is that these sand dunes are forming only about 44 miles away from Beijing at a pace of almost 2 miles each year. To prevent the capital city from being submerged in sand, the Chinese government must investigate new and creative ways in which natural ecosystems can be restored (Schwärzel, 2017, 21).

3 Sustainability Challenges in China

One of the factors contributing to the complex essentially complex nature of sustainability is that, in conceiving and presenting the goals of preserving sustainable strategies, sustainability appears as interdependent on the dimensions of entrepreneurship, innovation and competitiveness of economies. Indeed, the goal that is presented to us in the majority view on sustainability is "green capitalism," that is, not a sustainable global society with clearly established limits to growth, but rather the sustainability of the information and knowledge economy, to which reformers and planners add more or less ambitious commitments to the environment (Meadows et al., 2004). The Chinese case illustrates the possibilities, contradictions and limitations of this approach (World Bank, 2018).

In early 2019, the Chinese government approved three sustainable development zones, Shenzhen, Guilin and Taiyuan, which form the leading axis in Chinese innovation

(Ness, 2018). These zones are implementing the 2030 United Nations Sustainable Development Goals.

> Shenzhen is China's innovation engine. This zone will integrate technologies in sewage treatment, waste utilization, ecological restoration, and artificial intelligence to solve issues from resource management to pollution. Guilin will focus on innovations that tackle desertification, creating solutions that can be replicated by other regions facing the threat of encroaching deserts. Taiyuan, targeting air and water pollution, will foster innovative solutions that can be replicated by regions relying on resource extraction (XinhuaNet, 2018, 22).

Shenzhen, Guilin and Taiyuan function as large sustainable innovation districts (or *innodistricts*). In these newly developed urban areas, achieving sustainability usually means achieving environmental sustainability. This goal by itself, however, does not guarantee the sustainability of innodistrict development in the knowledge economy (Carnes, 2016). This objective must be pursued in a comprehensive and holistic way (United Nations SDG 2030), such that it is integrated with innodistricts, any infrastructure projects, industrial corridors for advanced manufacturing, factories of the future and other development projects. It ought to take into account:

(1) environmental sustainability, promoted by sustainable infrastructure and the creation of "sustainable development zones";
(2) sustainability in the design and planning of the development project;
(3) sustainability in management;
(4) institutional sustainability, aimed at the integration of all relevant *stakeholders*, and
(5) socioeconomic sustainability, based on a strategic alignment of the project's objectives with urban, regional and even national policies.

We shall develop and discuss these sustainability dimensions below when we discuss sustainability in innodistricts.

Complex sustainability, therefore, is an organic process that

> includes the environment, the economy and the community; form and efficiency (environmental factors in design, architecture, engineering and construction) and policies (plans and urban practices that aim explicitly to maintain and improve the social and economic well-being of citizens). Thus a development project can be defined as sustainable if it is planned and implemented to take into account the capacity, adaptability, resilience, diversity and balance of the ecosystem where it is located and of which it constitutes a symbiotic element (del Cerro Santamaría, 2019a, 26).

Despite this systematic and holistic approach, the limitations of many of the sustainability strategies underway today persist. Such limitations are seen in the fact that, to the extent that countries shift into the transition from urban property investment and finances to science, knowledge and innodistricts, what we see is that sustainability strategies, including environmental sustainability, are conceived as a central element in the positioning of the market.

> As cities and countries climb the industrial value ladder and expand their service sector to cater to growing domestic demand, environmental quality will become central to achieving sustainable economic growth. Urban residents in the more sophisticated markets are already putting a substantial price premium on high-quality urban environment (i.e., ecological or "sustainable"). To attract the right labor pool, cities will need to raise their game further (World Bank, 2018, 33).

Thus, in global cities like New York, London or Sydney, among others, certain strategies aimed at sustainability can have the perverse effect of gentrification (Curran, 2017), which starkly reveals the problems of anthropocentric sustainability. From this perspective, the planet continues to be considered exclusively a resource for human use.

4 Governing Sustainability in Innovation Districts

The geography of knowledge economy includes, as one of its paradigms, the *clusters* of high level and high added-value technological and scientific activity in the traditional technopoles (Castells & Hall, 1994). More recently, the growing importance of the innovation economy in urban areas and the desire of many companies to attract talent and know-how meant a concerted effort to provide better living conditions for their workforce. This has been a trigger for the creation and development of innovation districts in many cities of the planet.

These innodistricts (innovation districts) are

> geographical urban areas where institutions and leading companies are grouped together and connect with new companies, business incubators and accelerators. Compact, transit-friendly innovation districts with high-tech infrastructure encourage open collaboration, promote the pooling of talent, and offer attractive places to live (Katz & Wagner, 2014, 38).

The Brookings Institution estimates that there were about 100 innovation districts around the world in 2019. Barcelona, Boston, Berlin, Copenhagen, London, Medellin, Montreal, Seoul, Stockholm, Bilbao, Atlanta, Cambridge (Massachusetts), Detroit, Philadelphia, Pittsburgh, St. Louis, Toronto, Brooklyn (New York), Chicago, Portland, San Francisco and Seattle contain emerging or established innovation districts.

Some innodistricts, such as Barcelona @ 22, are based on planning and investment efforts directed by the government, under the premise that innovation districts can be effective tools for urban regeneration and economic

development. The decision to create an innovation district is usually "an attempt by urban and regional leaders to maximize their strengths and resources in order to emerge as a center of innovation in the knowledge economy" (Carnes, 2016).

Innovation districts contain economic, physical and network assets or *clusters*, and organize around a model of *triple helix* by which entrepreneurs are linked to universities and research centers to promote ideas. Innovative practices are sometimes supported by government funds in key ways, as Mazzucato has persuasively shown (Mazzucato, 2013). Universities, in turn, create new research and development opportunities and facilitate increased revenue streams.

Capital, technology and the built environment are tangible assets in the development of the innovation district. Intellectual density, impact innovation, and social and economic networks are intangible assets. Physical proximity and density can be promoted in a planned way. To create an entrepreneurial spirit, however, is far more complex. It requires long-term cultivation of crucial social, cultural and behavioral aspects. Intangible long-term social processes, such as the quality of education, leadership training and culture, or business ethics, play a fundamental role in the shaping of innovation cultures.

Among the requirements for the successful creation of innovation districts, one finds the value of collaboration between stakeholders and investors. The most powerful and effective innovations and innovation processes today originate in collaboration, the exchange of ideas, the combination of disciplines and the strategies of technological disruption.

Effective, multidisciplinary and open collaboration requires intellectual density (concentration of qualified actors and talent), diversity, close proximity, strong networks and partnerships between citizens, companies, laboratories, academic institutions and investors (Dall'Orso, 2019). For this reason, the efficiency of the innodistricts improves if they are integrated, or at least aligned in goals and objectives, in the regional and national innovation systems, and if their planning and management include actors or *stakeholders* external to the ecosystem of innovation.

Innodistricts are associated with a certain promise of sustainability over alternative urban development focused on financial investment and real estate speculation. The latter still benefit from a clearly favorable incentive structure. This limits the potential to optimize opportunities for investment in knowledge-intensive industries and activities.

Rather than primarily pursuing unrealistic growth targets through large capital-intensive projects (e.g. megaprojects), cities and regions may choose to integrate their innovation initiatives into their local context, history, and culture. This way they can nurture their strengths to address priorities such as affordable housing and accessibility to public services and education. This facilitates the possibility to create long-term, exponential and sustainable impact (dall'Orso, 2017).

Innodistricts, thus, represent the urbanization of the knowledge economy, growing around the links between science, technology, innovation and sustainability. Innodistricts are urban spatial locations for these ideas and practices. However, there is no consensus about the positive impact of innodistricts. For their detractors, innodistricts are

> useless from an ecological point of view, uncertain from an economic point of view, counterproductive from the point of view of habits. They even harbor false promises in an era of uncertainty and precariousness (Wagner, 2019, 46).

For example, the location and residential appeal of new neighborhoods can create new housing pressures that exclude some of the disadvantaged populations. Social mixing is in no way guaranteed by residential diversity: "Classical sociological studies show that neither social homogeneity nor social heterogeneity guarantee that individuals will actually socialize" (da Cuhna, 2013).

Many innovation districts underline its ecological orientation and sustainability means, in those cases, environmental sustainability. However, very often the focus of ecological relationships within the innodistrict reflects a structure of *ghetto* that operates in isolation with respect to the external environment. Synergies should be designed to cross-link to external conditions in the urban environment (Paquot, 2013). If the eco-district exclusively allows self-referential synergies, its urban development and sustainability objectives are in doubt, as is the case, among other cases, in Masdar City (Günel, 2019).

Supposedly, innovation districts have the potential to restore the promise of quality of life in neighborhoods, the value of sociability, solidarity, density and identity; they are presented as well as sustainable projects. However, the understanding of the kind of sustainability that innodistricts apparently promote requires careful analysis.

5 Sustainability Components in Innodistricts

As described above, achieving sustainability in innodistricts is not guaranteed by environmental sustainability alone. This objective has to be pursued in a comprehensive and holistic way. One way to do this is to use the notion of "multiple success factors" (Grunert & Elleegard, 1992) and take into account (1) environmental sustainability, promoted by sustainable infrastructure and the creation of "sustainable development zones" in which innodistricts would be

integrated; (2) sustainability in the design and the planning of the innodistrict; (3) sustainability in management; (4) institutional sustainability, aimed at the integration of all relevant *stakeholders* and (5) socioeconomic sustainability, based on a strategic alignment of the innodistrict's objectives with urban, regional and even national policies (del Cerro Santamaría, 2020b).

Let us recapitulate with the definition proposed above. An innodistrict can be defined as sustainable

> if it is planned and executed to take into account the capacity, adaptability, resilience, diversity and balance of its urban ecosystem. We consider sustainability as an organic process that includes environment, economy and community: form and efficiency (environmental factors in design, architecture, engineering and construction), as well as policies (urban plans and practices that explicitly target maintain and improve the social and economic well-being of citizens) (del Cerro Santamaría, 2019a, 34).

(1) **Sustainable Infrastructure**

The quality of urban infrastructure is key for the goal of preserving the natural environment. This ought to be the starting point for the coming shape of socioeconomic development. Those responsible for planning have to know how to integrate all the infrastructure subsystems using technology and decision-making protocols needed to obtain information in real time. This can make it possible to efficiently use the synergies between subsystems, which operate autonomously but are interrelated. The backbone of the next phase of infrastructure development

> should be the "one-system" approach. Infrastructure planners need to consider the development of the entire city-wide infrastructure system, including its energy, transport, land, and water subsystems. Realizing the potential synergies between subsystems will require technology for real-time information, conservation pricing, and demand management (Ness, 2018, 74).

Suppliers and infrastructure experts in these areas should be prepared to achieve higher infrastructure performance standards in the coming years.

> Government stimulus and financing will also be critical. Central governments can redouble its commitment to environmental sustainability by continuing to pursue aggressive resource conservation and economic productivity targets, and by backing those efforts up with funding for investment in infrastructure (United Nations, 2016, 41).

(2) **Sustainable Planning and Design**

Innodistrict planning should be oriented toward goals of social equity and to ensuring sustainable development rather than focusing solely on growth and competitiveness. Financial planning should avoid *strategic misrepresentation* and *optimism bias* regarding costs and benefits. The goal of sustainability could be facilitated by including commitment clauses by all *stakeholders* that ensure a fair distribution of benefits throughout the community.

> In the design process, contextual elements such as local history and culture should be important factors in interpreting architectural styles and assigning specific meaning (local, regional, national, global) to the architectural practices used to build innodistricts and make them visible (del Cerro Santamaría, 2013, 24).

(3) **Sustainable Management**

Innodistrict management must avoid the "exclusivity bias" among planners and managers, who tend to view their projects as unique, preventing them from learning from other projects.

> Indeed, there is often an over commitment to a certain project concept at an early stage, resulting in a "lock" or "catch." This makes the analysis of alternatives unlikely and leads to *ad hoc* compromises in later stages. Planning and operation of innodistrict activity are stochastically high risk, with exposure to so -called *black swans*, i.e., improbable events that end with massively negative results (Flyvbjerg, 2014, 42).

> Stakeholders should take this into account, rather than treating projects as if they really existed in a Newtonian deterministic world of cause, effect and control. Complexity and unplanned events must be taken into account; budgets and time contingencies must address that inherent complexity appropriately (Flyvbjerg, 2014, 45).

(4) **Institutional Sustainability**

One aspect that stands out as we study innodistricts is their relationships with pro-growth coalitions. One legitimate question is whether these large projects and the form of development they represent constitute a way of legitimizing the "engines of growth," growth machines and the commercial interests in urban areas. Public actors and state agencies responsible for regeneration and development also play a role in the shaping of innodistricts. Case studies and empirical research need to carefully find the particularities of this aspect.

In addition to growth coalitions, the governance of innovation districts must consider a variety of stakeholders in order to ensure institutional sustainability. There is no space in this document to adequately develop this argument, but I will simply mention the following aspects and *stakeholders* that should be taken into account: (1) the role of civil society; (2) the role of local context, history, and culture; (3) the importance of maintaining urban variety and diversity; (4) the importance of the local integration of the district in urban synergies, preventing

its *ghettoization*; (5) the role of public space in the design of the innodistrict; (6) the role of urban design professionals.

(5) **Socioe-conomic Sustainability**

The *embeddedness* or mutual integration of the multiple scales of socioeconomic action (from the local to the global level) is paradoxically linked to the tendency of the private sector to develop innodistricts independently of state and urban regulations. Therefore, aligning the objectives of these innodistricts with regional and national policies must be a priority. The emergence of new institutional agreements is vital to the implementation of strategic policies at administrative levels. Separating the primary objectives of the innodistricts from the objectives of the political realm usually yields negative results.

Therefore, innodistricts generally work as catalysts for urban development and regeneration.

> They can and should be used as tools at the national level to advance sustainability policy. The result can be an optimization of sustainable policy outcomes due to synergistic multiplier effects. From this perspective, the key question for future research would be how to plan and build innodistricts that simultaneously promote sustainability and competitiveness (del Cerro Santamaría, 2019a, 21).

After the above discussion, to what extent and under what conditions can we state that innovation districts are sustainable? There may be advantages in promoting innovation districts compared with urban regeneration strategies aimed at building megaprojects, to the extent that innodistricts serve to foster scientific and technological development efforts in cities and regions. The risk is that they can become, in a neoliberal urban context, elitist icons promoting urban innovation. They would, thus, replicate the non-sustainability of megaprojects and development strategies based on real estate, residential or commercial development. The disadvantages of megaprojects are well known: risk of gentrification, excess of expectations, lack of results, cost overruns, spatial polarization, socio-spatial segregation, among others.

Innovation districts are generally planned to encourage livability, regeneration, development, ecology and sustainability, and these are positive goals. They are districts that generate economic value for cities, but one of the drawbacks is the large increase in housing prices that they cause and, sometimes, the population displacements they trigger. As we have described above, certain strategies aimed at sustainability can have the perverse effect of gentrification.

Like culture and tourism, which became catalysts for urban economic prosperity but at the same time unleashed strong gentrification processes, innovation districts promote the growth of urban wealth, a process where we usually find winners and losers. Without adequate public policies that limit their negative impact, innovation districts do not promote sustainability but rather contribute to processes of dualization and socioeconomic polarization that are detrimental to the well-being of cities and countries.

6 Governance of Complex Sustainability

Innodistricts give us a good empirical reference to analyze the complexities of sustainability. This is an anthropocentric perspective on sustainability, which links it to entrepreneurship, innovation and competitiveness. In order to proceed toward a transdisciplinary framework guiding the governance of sustainability, however, we need to enrich such an approach to sustainability with contributions from new materialisms and transdisciplinary approaches, which favor a better understanding of sustainability's complexities, its mechanisms and purposes, and therefore its management.

The consensus established around the idea of sustainable urbanism tells us that we must strive to

> maximize the efficiency of energy and material resources, create a zero waste system, support the production and consumption of renewable energy, promote the neutrality of carbon, or zero carbon footprint (United Nations, 2016, 33).

We are also expected to reduce pollution, decrease transportation needs and encourage

> walking and cycling, provide efficient and sustainable transportation, and preserve ecosystems. Scalability of the design and spatial proximity (compact cities) are emphasized, which promote livability and communities's sustainable prospects (Lin & Gámez, 2018, 65).

The emission limits established by the European Union and other organizations, and the various ecological transition policies, determine what types of specific strategies should be implemented in each case and in each place (De Clara & Mayr, 2018). Indeed, although the *ethos* and *telos* of sustainability can be understood in a univocal way, it is a complex and multidimensional concept with many concrete variants, among other reasons because the zero or starting points of each human settlement differ.

"Complexity" refers to assemblages in which inseparability, inter-retroactivity, interactivity and interdependence prevail between the elements that form it and between the subject of knowledge and its context:

> Pertinent knowledge must confront complexity. *Complexus* means that which is woven together. In fact there is complexity whenever the various elements (economic, political, sociological, psychological, emotional, mythological …) that compose a whole are inseparable, and there is inter-retroactive, interactive, interdependent tissue between the subject of knowledge and its context, the parts and the whole, the whole and the parts, the parts amongst themselves. Complexity is therefore the bond between unity and multiplicity. Developments proper to our

> planetary era confront us more frequently, ineluctably with the challenge of complexity (Morin, 1999, 15).

The Latin word *complexus* means "intertwined", "twisted." We can define it as a joint or union of two or more things that constitute a unit and that is composed of different elements. Here, we find the basic duality between parts that are at the same time different and connected, which indicates that something complex requires two or more components that are linked in such a way that it is difficult to separate them.

> Since the components of a complex cannot be separated without destroying it, the method of analysis or decomposition into independent modules cannot be used to develop or simplify such complexes. This implies that complex entities will be difficult to model, that eventual models will be difficult to use for prediction or control, and that complex problems will be difficult to solve (they are *wicked problems*). Complexity contains simultaneously order (the connection between the components) and disorder (variety and heterogeneity) it is therefore permanently in unstable equilibrium, even to the edge of chaos (Edmonds, 1996, 45).

Urban complexity can be said to emerge

> from the decentralized and self-organizing webs, assemblages and networks of transactions and interactions among a wide range of heterogeneous actors, agents and stakeholders that typically occur at multiple scales in dynamic, fuzzy, changing and uncertain urban settings. These transactions and interactions of cooperation and competition, informed by serendipity and randomness, highlight agents' perceptions, choices, decisions and preferences (Batty, 2008, 27).

Agents, actors, actants and stakeholders can be individual, community, city and regional, involving social, economic and political institutions. Their mutual interactions produce feedback loops that allow the adaptation of individual and group actors and the emergence of phenomena, patterns and outcomes (physical, behavioral, social, economic, ecological, environmental) that cannot be predicted by analyzing the particular webs, assemblages, networks and their constituents and components (Alexander, 1965; Barabasi, 2003; Bunge, 2014; Miller, 2016).

To the complex nature of sustainability contribute not only the scope and variable geometry of its own sustainable practices but also the overall socioeconomic context where it has been recently developing and the situation of crisis and uncertainty to which is applied as a possible *strategy to contain systemic risks*.

Some elements in this situation are known: (1) the unpredictability introduced by the mechanisms of action at a distance in globalization and the increased inequalities and consequent transnational migration flows that has caused; (2) the complexity in the global territorial organization, which reflects not only an incessant *planetary urbanization* (Brenner & Schmid, 2011) but also the formidable challenges of the ecologies of towns and regions (Forman, 2019); (3) the relative decline of the West and the tectonic shift in the center of gravity of the global economy to Asia, coupled with geopolitical multipolarity and the rise of geo-economics and geo-technology (Lee, 2018); (4) the profound disruption of production and labor triggered by the informational and technological revolution of the last 30 years (Stiegler, 2019); (5) the emergent understanding of the Earth system as a variable, responsive, adaptive and self-regulating mechanism in the Anthropocene, which calls for re-centering (or, better, de-centering), within the universe of life, the human being and its mechanisms for the production of knowledge and transformation of the environment (Latour, 2016; Margulis, 1999).

7 Sustainability, Mind and Matter

The prevailing idea of sustainability evokes an environmentalism without an environment and an ecology devoid of living creatures that are not human beings. A standard definition of sustainability that remains in force is that expressed in the 1987 Brundtland report: development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). Not only are "generations" considered here to be human but also the animate world is reduced to that which can satisfy human needs.

Faced with this anthropocentric attitude, the new materialisms recognize the pre-eminence of objects, things and matter over mind and ideas (Harman, 2002). Its relevance comes from accepting that the open gaze to a radically transformed world and the observant attitude must prevail over the existing conceptions, visions, plans, analyses or solutions based on the schemes that created the problems that we need to solve.

Within urbanism,

> the new materialisms propose to interpret the built environment as an inescapable material reality that can be understood from the outside, through 'the observation of concrete materials, not from the functioning of the isolated mind'. Jane Jacobs already noted that buildings, streets and neighborhoods function as dynamic organisms, changing in response to how people interact with them (Sennett, 1992, 192; Jacobs, 2000, 35).

This perspective facilitates the understanding that city and nature (culture and nature) are very closely interrelated ideas. Both are organized complexity and both are distant from any self-regulating harmony.

> Darwin does not celebrate nature as an autonomous and self - regulating internal harmonious relationships always returning to equilibrium, but the small differences that can suddenly become significant differences as a result of geographical drift and climate change. He is also interested in the kinds of transversal and cross-species relationships that generate new vectors of

> becoming leading in totally surprising directions, something very similar to what happens in the city as organized complexity (Morton, 2009).

"Nature," then, is not "the other" in an increasingly urban world, but a new way of thinking

> about the sustainable integration of all sentient beings and the environment. What we call "environment" is always a combination of nature and culture, and both express the creativity, emergence and self-organizing power of complex adaptive systems. In turn, the natural thing is the preservation of the world, that is, its sustainability, and this attitude is necessary above all in urban environments, but also in non-urbanized or hardly urbanized environments (Morton, 2019, 37).

For this reason, the idea of *urban ecology* expresses the way of thinking about "the natural" in our time.

> The anthropocentrism that underlies the dominant ecological vision is perhaps the main ideological obstacle that prevents the achievement of sustainability, since it does not treat nature as a community to which we belong but as an external ideal that must be pursued to save ourselves (del Cerro Santamaría, 2020c).

Faced with anthropocentrism, the new materialisms invite us to know and re-know life, matter and the planet. We must not know by defining the objects of knowledge, but by responding to the immanence of vibrating matter, its influences, results and consequences. In this sense, the French sinologist François Jullien has stated that "a wise man does not have ideas" that are independent of matter (Jullien, 2001). Thus, if continue "sleepwalking" regarding the ecological crisis (Sklair, 2017) it is possibly because we have not acquired the capacity for mutual involvement with matter that allows us to be truly human (Bonshoms, 2007).

New materialisms can enable the adoption of more robust sustainability strategies by highlighting the connections between norms, technologies, and worlds of life through networks of human associations, natural ecologies, mechanisms, devices, places and environments. The focus on matter allows us to move away from the secular attitude of placing humans at the center of reality and experience and instead look around to see the power of the "forgotten masses," that is, the artifacts that populate the world (Latour, 1992).

A material conception of sustainability affects how we conceptualize space, place, scale and context, as "places" are places and environments that interact with the practice of the planning of development in significant ways. *Place* is not to be seen as a topological but as a relational space, a notion originating in Leibniz (Lefebvre, 1992). Such a relational notion is structured around configurations of humans, non-human life and material artifacts.

The complexity of material sustainability is thus far from the formal harmony of a system; it is more like a whirlwind in motion or a heterogeneous, non-linear and non-hierarchical assemblage. He responds to the idea of "baroque complexity," where the parties are neither components of a cohesive whole nor insignificant and powerless, since they are not isolated (Beauregard, 2015).

The sustainability of the economic development process in conjunction with processes of capital mobility, the formation of network states or planetary urbanization, among other elements, can be approached from one material perspective where the global is intrinsic to the local and where mind and matter are parts of the same assemblage.

8 Conclusions: Transdisciplinary Sustainability

Complex sustainability requires new analytical tools (or transforming the ones we have) to capture and understand the heterogeneous, dynamic and changing assemblages that cause the unpredictability and uncertainty of the Earth system in the Anthropocene. With this understanding, perhaps viable strategies to contain systemic risks can be forged in the "somber clarity of chaos," which does not invite us to expect a new order in the near future (Castells, 2018). The new materialisms point in this direction, as do transdisciplinary approaches (Gibbons et al., 1994).

In both cases (materialism and transdisciplinarity), the overcoming of binary logics and the distancing of anthropocentric approaches are postulated. The focus is on complexity, hybridization, non-linearity, reflexivity and heterogeneity. As discussed above, in both cases, it is assumed that sustainable development planning does not occur in a context of determinism where control, causes and effects can be used for establishing predictions. Instead, what we have is the high probability of finding events yielding extremely negative results.

Both sustainability and sustainable development are concepts that refer to the ability of systems to absorb disturbances, evolve and co-evolve with other systems with which they interact. It seems, therefore, reasonable that policies related to sustainability (pursuing a transformation of social organization and economic activity) be designed on the basis of a transdisciplinary perspective. By using such an approach, questions that are relevant to address systemic problems in changing environments can be formulated collaboratively with the analytical tools contributing to fully understand its complex nature.

Indeed, a transdisciplinary approach is advantageous in order to understand the complexity inherent in sustainability science, since pursuing sustainability requires understanding and managing unprecedented and interconnected challenges. Increasingly, science and knowledge production are geared toward overcoming of classic disciplinary questions and approaches, integrating perspectives of different *stakeholders* (experts and citizens, academics and professionals) and

showing to be particularly receptive to contextual differences and local knowledge (Elmqvist et al., 2018; del Cerro Santamaría, 2019b, 2020a).

In addition to including the general principles of integration of *stakeholders*,

> cooperation and containment of risks, transdisciplinary approaches to sustainability are usually oriented to scientific research on new technical and institutional alternatives. Indeed, knowledge innovation strategies are crucial to better align practices related to the use of resources with heterogeneous ecological and socioeconomic conditions, and to be able to adapt to unforeseen changes (Brandt et al., 2013).

Although sustainability can be approached as a practice that unifies the base of material ecosystems and resilience (maintaining levels of activity and equity versus internal and external perturbations), from an interdisciplinary perspective the strategies and policy responses, policies would need to consider the unpredictability, variability and heterogeneity inherent in the functioning of such eco-systems (Waltner-Toews et al., 2008).

The practice of transdisciplinary research still needs to develop significantly. There is no common glossary, not a shared communication platform or a single research framework. A transdisciplinary attitude and practice-seeking integration, complexity and holism may not be capable of producing a shared instrumental canon, but it nevertheless fulfills its function by raising awareness about the need to co-create knowledge in the interstices between disciplines.

From these gaps, one can clearly observe the assemblages of material sustainability, which is not a problem to be solved, but a complex normative strategy whose mechanisms and purposes we need to understand better in order to manage them effectively and handle them appropriately in a context socioecological concern (and even alarm), structural uncertainty and global risks.

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