Using metaphors for addressing urban sustainability

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Enhancing the sustainability of cities is a timely, complex task. It involves the challenge of identifying the concerns and goals of different stakeholders in an inclusive manner and bringing into dialogue the various forms of knowledge and know-how that can address these concerns. At the moment, the lack of suitable concepts and methods for taking on this challenge limits our ability to conceive appropriate measures for promoting the sustainable development of cities. We propose three theses outlining the value of metaphors in tackling the challenge, demonstrated through the analysis of three prominent urban metaphors, and as an outcome, suggest three avenues for future work. With our contribution, we wish to encourage the construction of new approaches to urban sustainability based on transdisciplinary knowledge creation and the inclusive acknowledgement of different sustainability requirements.

1. Introduction

Currently, the majority of people live in urban areas (UN-Habitat, 2020), and cities represent centers of socio-economic activity, innovation and change (Sassen, 2005; Balland et al., 2020). As a result, cities dominate global resource use, with correspondingly high environmental impacts on surrounding land and the planet more broadly (IPCC, 2014). Therefore, the organization and development of urban areas constitutes a crucial determinant of all dimensions of sustainable development. This has placed the notion of urban sustainability in an increasingly central position of interest in both political and scientific domains (UN, 2017; Lobo et al., 2020).

Tackling urban sustainability remains a formidable task, with at least three distinct challenges for research and policymaking. Firstly, moving towards urban sustainability involves satisfying a complex set of parallel requirements (Finco and Nijkamp, 2001; Dempsey et al., 2011). Therefore, the first challenge is in identifying and acknowledging these requirements in a manner that is adequately comprehensive and representative of the different stakeholder priorities in city development (Turcu, 2013). Secondly, successfully addressing the multitude of requirements in urban sustainability entails incorporating a broad spectrum of knowledge and know-how (Ramaswami et al., 2012; Acuto et al., 2018). This, however, is not a trivial task, since the manner in which cities and their sustainability are conceptualized varies greatly across different fields and scientific disciplines (Portugali, 2011). Thirdly, urban sustainability is not a universal concept, but rather reflects contextually specific key issues and priorities (Kates et al., 2005; Hartmuth et al., 2008). This necessitates the tailoring of approaches to specific geographical and historical settings.

Given these challenges, a need exists for concepts and methods that can aid in identifying and bringing into dialogue a broad variety of ontological, epistemic and normative perspectives (Vilsmaier et al., 2017; Elmqvist et al., 2019; Norström et al., 2020; Zhou et al., 2021). Currently, work in this direction is only nascent, and significant conceptual and methodological advances remain to be achieved (Lobo et al., 2020). In response, this paper puts forward the idea of engaging with *metaphors* as a means of facilitating the creation of more comprehensive understanding of perspectives to urban sustainability. In particular, we put forward three theses:

- *Thesis 1: Metaphors can clarify and represent different aspects of urban sustainability*
- *Thesis 2: Metaphors can facilitate transdisciplinary approaches to urban sustainability by clarifying focuses and boundaries of forms of knowledge and know-how*
- *Thesis 3: Metaphors can convey visions of urban sustainability that are appropriate for particular contexts*

Our argument draws upon a dialogue between academics from different disciplinary backgrounds and a set of eight workshops through which an initial idea (Halla et al., 2020) was critically reviewed, discussed and elaborated into the three previously mentioned theses. With this contribution, we aim to encourage the construction of new approaches to urban sustainability based on transdisciplinary collaborative knowledge creation and the inclusive acknowledgement of different aspects of sustainability. We believe this line of work is crucial for finding more effective ways to conceive and apply urban sustainability measures and strategies in the 21st century.

2. Metaphors - from everyday language to science

As George Lakoff and Mark Johnson argued in their 1980 work *Metaphors We Live By*, metaphors provide a fundamental cognitive mechanism that structures our interpretation of things we observe and experience (Lakoff and Johnson, 2003). They do so by invoking the imagery of familiar and well-understood phenomena to describe other phenomena that are more opaque, either because they are more complex or because a proper conceptual repertoire for describing them is not yet at hand (Barnes and Duncan, 1992).

The use of metaphors is not limited to informal language but also extends to the scientific domain in disciplines as diverse as physics, economics and anthropology (Barnes and Duncan, 1992). Metaphors help scientists chart the unknown by tentatively assigning sameness and difference, and subsequently by stimulating the creation of technical concepts and models to be used for the scientific analysis of the phenomena in question (Pickett et al., 2004). This is particularly the case when analyzing complex phenomena, where creativity and inspiration are needed for recognizing patterns and processes beyond the individual elements involved (de Roo et al., 2012).

Metaphors are also ubiquitous in our vocabulary of cities (Nientied, 2016). During the last 100 years terms such as ‘machine’ (Le Corbusier, 1997), ‘neo-liberal’ (Harvey, 2007), ‘global’ (Sassen, 2005), and ‘networked’ (Castells, 1996) were applied to metaphorically describing cities, each offering a specific reading of the city, and each focusing on a specific aspect of urban reality. The value of such terms is in providing a heuristic conceptual foundation that helps to unravel the complexity of urban phenomena. The use of city metaphors also has a temporal dimension, in that at different points in history different metaphors have served as aspirational images for the organization and development of cities (Lynch, 1984).

The use of metaphors, however, involves juxtaposing objects that are not identical, which means that certain aspects of the target object are highlighted while others are effaced (Newell and Cousins, 2015). The use of metaphors thereby implies the taking of a normative position on which aspects of the target object are important to consider (Lakoff and Johnson, 2003). Especially, when metaphors serve as inspirational building blocks for scientific theories and models, awareness of this limitation of metaphors, as well as of the translation process from metaphor to theory and/or model is crucial (Henle, 1996), as it can help to clarify the focal points and limits of knowing inherent to the respective scientific disciplines.

3. Comparing urban phenomena metaphors

The awareness of the perennial influence of metaphors on our thinking about cities triggered the organizing of a series of workshops to discuss among an interdisciplinary group of researchers the idea of employing these metaphors in support of efforts towards urban sustainability. During the workshops, consisting of collaborative and iterative conceptual analysis (Cornwall and Jewkes, 1995; Kerssens-van Drongelen, 2001), the participating group explored both the potentials and the limitations of metaphors in such a task (see supplementary material for notes on methodology). Our

group also discussed and jointly completed a comparative table to support the argumentation (see Table 1). The table concretizes the meaning of selected metaphors across a number of aspects: (1) the key sustainability requirements implied by each metaphor; (2) their principal focuses and fields of application; (3) the contexts in which they are most appropriate for describing urban sustainability. The comparative table allows us to illustrate our three theses on the possible role of metaphors in facilitating the kind of integrative work and dialogue across fields of knowledge and know-how needed for successfully moving forward on urban sustainability.

Our example includes three metaphorical terms prominently used to describe urban phenomena: *metabolism*, *rhythm*, and *smart*. These three metaphors do not, of course, represent the full picture of urban sustainability; they were chosen for demonstrative purposes, covering a variety of distinct epistemological and historical perspectives. For example, while the rhythm metaphor has been employed by authors from Aristotle to Sharon Zukin (Smith and Hetherington, 2013), the metabolism metaphor entered wider use during the 20th Century as cities' environmental impacts became more critical (Kennedy et al., 2011), and the smart city metaphor gained prominence only as recently as the 1990s (Angelidou, 2015). The three metaphors also vary in their field of societal application (e.g., the notion of smart city being popular with policymakers and technology companies, while metabolism is mostly used in academia).

4. Thesis 1: Metaphors can clarify and represent different aspects of urban sustainability

As mentioned in the introduction, urban sustainability is a multidimensional challenge, which entails the balanced satisfaction of parallel social, economic and environmental requirements (Finco and Nijkamp, 2001; Dempsey et al., 2011). Despite an extensive amount of literature addressing the topic, a degree of fuzziness persists around the concept of urban sustainability, and its definitions typically remain at the level of abstract principles (Huang et al., 2015). This renders the concrete operationalization of the concept a particularly challenging task. In particular, the operationalization must consider different aspects and requirements of sustainability in an adequately comprehensive and balanced manner. However, observations of current practice often reveal an imbalance in the attention accorded to different dimensions of urban sustainability (Opp, 2017; Merino-Saum et al., 2020), which can at least be partially attributed to a lack of solid conceptual foundations to guide the operationalization processes (Turcu, 2013).

We argue that engaging with metaphors describing urban phenomena can help to tackle this challenge. In particular, by providing an effective shorthand for expressing different aspects and requirements of urban sustainability, discussing such metaphors can support ensuring that related efforts are constructed based on a clear and comprehensive understanding of the concept. The example of Table 1 demonstrates our point.

When applied to cities, the metabolism metaphor draws attention to the use of physical resources in support of urban activities, and to the associated environmental and social impacts. It suggests that to be sustainable, a city must reconcile resource use with the carrying capacity of the source ecosystems, and that within the city said resources must be distributed adequately to sustain different groups and functions. Common indicators relatable to this perspective on urban sustainability include statistics on energy consumption, waste production, recycling rates, and accessibility to basic services.

Metaphor	*Metabolism*	*Rhythm*	*Smart*
Working definition	*"The chemical and physical processes by which a living thing uses food for energy and growth"* (Cambridge Dictionary)	*"A strong pattern of sounds, words, or musical notes that is used in music, poetry, and dancing"* (Cambridge Dictionary)	*"Intelligent, or able to think quickly or intelligently in difficult situations"* (Cambridge Dictionary)
Clarifying and representing different aspects of urban sustainability (Thesis 1)			
Implied requirements for a sustainable city	● Use of resources adapted to carrying capacity of supporting ecosystems ● Minimal waste production ● Accessibility and fair distribution of resources	● Energy consumption adapted to natural rhythm (production of renewable energies) ● Deceleration of lifestyles (consumption, mobility, etc.) for improved human well-being ● Harmonious orchestration of urban activities	● Efficient and productive use of infrastructures ● Enhanced measurability and controllability that allows optimization ● Convenient urban life
Characteristic sustainability indicators	● Carbon footprint per capita ● Material unit per unit of service (MIPS) ● Waste production per capita ● Percent of population with access to potable water	● Modal split of transportation ● Peak hour capacity of the public transport system ● Time use satisfaction (survey) ● Changes in the balance of renewable/fossil energy use	● Energy consumption per GDP ● Number of hours spent in traffic jams ● Number of households with smart meters ● Existence of online government platforms
Clarifying focuses and boundaries of forms of knowledge and know-how (Thesis 2)			
Examples of use in science and practice	● End of 19thC. Marx: "the appropriation of nature by the capitalist extractivist economy" ● Industrial ecology (Wolman, 1965) ● Urban political ecology (Heynen et al., 2006) ● Related to, e.g., the circular economy movement	● 4th-century B.C. Plato "Order of the movement" ● Rhythmanalysis (Lefebvre, 1992) ● Critique of social acceleration (Rosa, 2010) ● Related to, e.g., the degrowth movement	● Early 20th Century futurists (Angelidou, 2015) ● Innovation studies (Komninos, 2009) ● Related to public policies aiming to improve functionality of cities; energy efficiency; etc. (e.g. EU Partnership for Smart Cities and Communities)
Urban issues in focus	● Resource use ● Urban services provision ● Processes of composition and decomposition; pollution/emission control	● Temporal regulation of flows of energy, materials ● Everyday movements (traffic, commute, etc.) ● Time pressure and human well-being	● Infrastructure management (transport, energy, waste) ● Information/digital traces ● Technological development
Conveying contextually appropriate visions of urban sustainability (Thesis 3)			
Context when most appropriate	● Historically: from mid-20th Century with increasing consumption load on the environment ● Today: Cities with high environmental footprint; rapidly urbanizing areas	● Historically: Industrial revolution in Europe (19th century); Functional revolution during 1960s; Digital revolution (e.g., 21st century Asian cities) ● Today: Large, dense, rapidly growing cities	● Historically: Since the emergence of ICT ● Today: Larger cities with resources to invest in technologies

Table 1. Comparing three metaphors used to describe cities and urban phenomena.

In contrast, the rhythm metaphor focuses on the temporal orchestration of urban life. As such, the metaphor suggests that to enhance urban sustainability is to improve the temporal patterns of resource use, movements of people and goods, and urban lifestyles in general. In addition, it implies a concern for the balancing of these temporal patterns in view of increasing human well-being and social cohesion, as well as emancipating people from the pressures of social acceleration. Possible indicators for expressing this point of view on urban sustainability include the capacity of the public transport system (in response to peak hours), the temporal variation in renewable energy use, and surveys of time use satisfaction.

The smart city metaphor evokes a city whose operations and development are rendered more controllable through technology. The metaphor suggests that the sustainability of cities depends on the efficient organization and continuous optimization of its functions. Characteristic indicators for this perspective to urban sustainability include metrics such as energy consumption per unit of GDP, the fluency of traffic (e.g., number of hours lost in traffic jams), and the existence of digital platforms for citizens to interact with authorities.

As these three examples show, metaphors can powerfully act as orientational terms that capture different aspects of urban sustainability, including particular urban processes (metabolism), attributes (rhythm) or qualities (smart). Therefore, they can support the creation of understanding and agreement on the meaning of the concept, as well as allow for moderation between its various operationalizations. Especially when it comes to the use of indicators in the sustainability assessment of cities, anchoring these indicators on specific metaphors may elevate them from loose metrics to meaningful messages.

The comparison of the three metaphor-based perspectives, each with their unique angles on cities, underlines the need to engage simultaneously with multiple perspectives, as no single perspective can capture all required aspects of the multidimensional concept of urban sustainability. As in our example, metaphors can act as catalyzers in attempts to acknowledge a more comprehensive range of sustainability aspects.

Summary:

- Metaphors have the potential to help imagining and expressing different aspects of urban sustainability.
- Engaging with metaphors could help to facilitate the simultaneous inclusion of a multitude of sustainability aspects, thus enhancing the comprehensiveness of efforts and assessments targeting urban sustainability.

5. Thesis 2: Metaphors can facilitate transdisciplinary approaches to urban sustainability by clarifying focuses and boundaries of forms of knowledge and know-how

The multidimensional nature of urban sustainability also implies that it cannot be adequately addressed by monodisciplinary approaches. Instead, the construction of successful policies and solutions for tackling urban sustainability must involve knowledge co-production both across scientific disciplines and between academic and other societal actors (Turcu, 2013; Acuto et al., 2018; Norström et al., 2020; Zhou et al., 2021). This calls for tools that allow for the inclusive integration of a wide variety of existing knowledge and know-how on cities (Bammer et al., 2020).

To illustrate this variety, Portugali (2011) presents three distinct ‘cultures’ among approaches to cities. The first of these cultures consists of approaches inspired by natural, engineering and economic sciences (e.g., Auerbach, 1913; Lösch, 1954) and essentially views cities as comparable to natural systems and subject to analysis through formal theory and quantitative methods. The second culture,

often explicitly critical of the first culture, is rooted in qualitative social sciences and humanities (e.g., Lefebvre, 1968; Harvey, 1973), and views cities primarily as settings of social and political processes. Finally, the third culture is more recent, based on the vision of cities as complex systems of networks and flows, with emerging properties and dynamics of self-organization (e.g., Batty, 2017)**.** The third culture is also related to the strong emergence of big data-based computational methods for studying cities (Creutzig et al., 2019).

As Portugali's presentation exemplifies, fundamental paradigmatic differences exist between different approaches in terms of how they imagine, conceptualize and analyze cities and urban sustainability. The first step towards bringing them into dialogue and collaboration consists of clarifying their basic assumptions, focuses and positions vis-à-vis each other. On one hand, this entails 'boundary critique' (Ulrich, 1994), i.e., critical reflection on which issues and values are included or excluded in a given approach to urban sustainability (Achterkamp and Vos, 2007), and on the other hand, 'boundary work' (Gieryn, 1983), i.e., efforts to understand the meanings of and differences between different forms of knowledge in view of their eventual integration (Mollinga, 2010). For these purposes, so-called 'boundary objects' are needed to allow communication across knowledge fields without necessarily having mutual in-depth understanding or consensus (Star and Griesemer, 1989). We argue that metaphors can serve as such boundary objects, and again demonstrate our argument briefly with the example of Table 1.

The term 'metabolism' was originally coined by the physiologist Theodor Schwann in 1832 to describe cellular and organism phenomena. Shortly after, Karl Marx used the term metaphorically in his description of the appropriation of materials by the capitalist mode of production. Today the use of the metabolism metaphor in urban contexts is associated with three separate fields (namely, industrial ecology, urban ecology and urban political ecology), each of which is interested in a systemic understanding on how urban activities impact the environment, but each also considering the matter from different angles. The use of the urban metabolism originally focused predominantly on the economic and environmental pillars of sustainability (and their connection), while struggling to understand the broader societal implications of resource use and pollution emission flows. However, the use of the metaphor has evolved considerably over time, and now also covers such sociopolitical implications. In particular, researchers that fall within the industrial ecology realm might focus solely on the environmental impacts of anthropogenic activities, while the ones falling within the urban political ecology realm would examine the power relations of who accesses, uses and dictates some of these resource and waste flows (Newell and Cousins, 2015).

The use of the rhythm metaphor dates back to Plato, and it is associated with several domains of philosophy, sociology and psychology. For example, the 'rhythmanalysis' approach developed by Henri Lefebvre (1992) analyses the intensity and periodicity of territories and social interactions. In psychology, scholars have more broadly focused their research on time pressures and their deleterious effects on the well-being of individuals. The analysis of urban rhythms has also raised the prospect of formulating dedicated rhythm policies (Antonioli et al., 2021) to address such issues as the temporal distribution of mobility, production, (energy) consumption, and overall time pressure on everyday life.

During the last two decades, the use of the smart city metaphor has featured prominently in the vocabulary of policymakers and technology companies to describe and inspire the use of digital technologies in the organization and development of urban areas. The metaphor is related to terms such as digital city, information city, etc., that preceded it during the 20th Century (Angelidou, 2015). Smart city initiatives often involve close collaborations between public authorities and private technology companies. The primary focus of these initiatives is evidently on the enhanced and more efficient delivery of urban services, including energy, transport, etc., with the help of new technologies. As such, the use of the metaphor has been criticized for excessive optimism in technological solutions

at the expense of more fundamental societal changes, as well as for lack of attention to questions of equality and access (Vanolo, 2014; Angelidou, 2015).

As these examples show, metaphors can serve as powerful reference points for making visible and for reflecting on the basic assumptions, focuses and boundaries of different approaches to urban sustainability ('boundary critique'). In addition, metaphors can serve as boundary objects, facilitating communication and collaboration between these approaches ('boundary work'), as they are "both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989, p. 393). In other words, metaphors can provide a starting point for a transdisciplinary dialogue in view of transdisciplinary co-production of more comprehensive forms of knowledge.

Our discussion also implies that the meaning of particular metaphors is not absolute, but rather evolves over time, both as the fields that are associated with them develop and respond to criticism directed at them, and also as the source objects of the metaphors evolve. It is a reminder that to avoid obsolete or caricaturistic representations, it is necessary to periodically update boundary judgments on what is included or excluded in a given metaphor and the knowledge fields related to it.

Summary:

- Metaphors could be used in boundary critique and boundary work to clarify the focal points, limits and relative positions of different approaches to cities and urban sustainability.
- Metaphors could support transdisciplinary research and construction of integrated forms of knowledge and know-how, both across scientific disciplines and between academic and other societal actors, in order to better address the current challenges related to urban sustainability.

6. Thesis 3: Metaphors can convey visions of urban sustainability that are appropriate for particular contexts

As is commonly accepted, the concept of sustainability always acquires a meaning that is context-specific (Kates et al., 2005; Hartmuth et al., 2008). When it comes to urban sustainability, this context-specificity has at least three dimensions. Firstly, the definition of the concept reflects local circumstances (such as geography and climate) and community preferences (Turcu, 2013). Secondly, the meaning of sustainability varies depending on the particular stage in the evolution of a city. For example, Bai and Imura (2000) show how the most pressing urban challenges evolve from poverty to production-related and then to consumption-related issues in the economic development of a city. Thirdly, the variability in the interpretation of urban sustainability also reflects changes in broader cultural expectations, worldviews and thought styles. Indeed, such changes across different historical epochs have also been reflected in popular and scientific conceptions of what makes a city 'good' (Lynch, 1984).

Again, we argue that metaphors could provide a powerful means of expressing these contextually variable understandings of urban sustainability. Our argument is demonstrated by the comparison of Table 1. The metabolism metaphor is most relevant in the context of cities whose environmental footprints are high to the point of starting to reach the carrying capacity of supporting ecosystems. The prominent use of the metaphor therefore coincides with an increasing awareness and concern for the need to moderate these footprints, which began in the 1960s, and which today is expressed e.g., in the call for more circular economies.

The rhythm metaphor, historically, is interesting when considering important epochal changes (e.g., the Industrial Revolution), and how they have affected the everyday life of urban dwellers. Today,

rhythm metaphor is particularly relevant in large and densely populated cities where mass transportation and communication has increased the speed of everyday life, and where commerce and services are in constant operation.

The metaphor of the smart city, then, is most relevant when describing present day cities facing the challenge of efficient organization of their functions (e.g., energy and transport) and that have the capacity and willingness to invest in technologies for solving these challenges. In fact, the smart city metaphor has become a global symbol of the quest for urban modernity (Glasmeier and Christopherson, 2015), prevalent in urban policy discourses on all levels of government (Datta, 2019).

As these examples show, metaphors provide a language through which to describe contextually specific and evolving interpretations of urban sustainability. Associating such interpretations with specific metaphors makes it possible to better appraise the results of sustainability assessments in different contexts as well as compare different assessment practices and approaches. Discussing contextual interpretations through evocative metaphors can also make the concept of urban sustainability more broadly accessible and subject to public deliberation.

Furthermore, the use of metaphors is in a co-constructive relationship with evolving reality (Jasanoff and Kim, 2015). The promotion of new, imaginative metaphors for envisioning cities has therefore the potential to not only deepen and refine our understanding of urban sustainability, but provoke the kind of cultural and social change needed for the creation of more sustainable cities.

Summary:

- Metaphors could help cities illustrate particular characteristics and sustainability needs given their historical and geographical contexts (and our evolving understanding of them).
- Metaphors could be a constitutive element when it comes to forging the imagination and conceptualization of what a (sustainable) city is throughout time.

7. Looking ahead - implications for research and practice

The use of metaphors is a cognitive tool that permeates both informal everyday life and more formal intellectual activities. Instead of dismissing metaphors, we argue, the more productive choice is to make their use more explicit and reflective. For efforts targeting urban sustainability, metaphors could be of particular use in clarifying the different required aspects for a sustainable city (Thesis 1), facilitating transdisciplinary work and dialogue across fields of knowledge and know-how (Thesis 2), and conveying contextually relevant interpretations of sustainability (Thesis 3). Based on our theses, we suggest three possible paths forward while also issuing a warning about the pitfalls related to metaphors. Please see supplementary material for more precise suggestions for pursuing these pathways.

Pathway 1: Investigate the deliberate use of metaphors to facilitate collaboration between citizens, policymakers and scientists

As we have argued, urban metaphors could act as boundary objects in transdisciplinary knowledge co-creation. Metaphors can facilitate communication between actors with different backgrounds and with conflicting interpretations and opinions of the concept of sustainability, as well as make the respective focuses and limitations of different approaches more tangible. This is a necessary first step in bringing the various urban stakeholders into dialogue and opening the door for the integration of different viewpoints into comprehensive policies. Therefore, we suggest investigation of the deliberate use of metaphors in a participatory procedure aimed at the development of new urban development policies.

Pathway 2: Construct sustainability assessment frameworks with metaphor-based indicator categories

As seen in Thesis 1, metaphors can effectively capture different aspects of urban sustainability. When constructing indicator frameworks for the assessment of urban sustainability, metaphors can act as guiding labels for categories of indicators, both inspiring the selection of these indicators as well as communicating their meaning. In particular, connecting the indicators used in an assessment to particular metaphors creates transparency concerning the underlying assumptions and prescriptive ideas held by those in charge of selecting the indicators. Still, no single metaphor can capture all aspects of urban sustainability. Therefore, attempts at metaphor-based sustainability assessments must simultaneously consider sets of metaphors, with each metaphor drawing attention to particular sustainability aspects and calling for a certain group of indicators.

Pathway 3: Investigate the dynamic interplay between metaphors and the urban phenomena they describe

Urban metaphors not only change as a response to the evolving reality that they describe, but by inspiring urban development they play a performative role in changing that reality. For example, certain metaphors can remain influential for a long time even when the metaphor has already lost its pertinence in describing current urban challenges. Awareness of this evolving bi-directional relationship between cities and metaphors over time can provide valuable critical perspective into the analysis of current practices in urban development. Moreover, analyzing the emergence of new metaphors can provide a means of anticipating urban challenges and our evolving understanding of them. In the future we may be confronted with challenges requiring entirely new approaches and knowledge forms related to cities – and the metaphors for anticipating them might already be at hand.

Be mindful of pitfalls when working with metaphors in the context of urban sustainability

The value of metaphors has limits, and their expediency in describing complex phenomena is accompanied by certain potential pitfalls (Newell and Cousins, 2015). Firstly, metaphors should not be taken literally. For example, a city is not a machine, nor an organism, etc., even though some aspects may be similar. Therefore, the requirements that apply to evaluating whether a machine or an organism is sustainable only partially cover the requirements for a sustainable city. In other words, care should be exercised in considering the extent of a metaphor's applicability. Secondly, metaphors are in constant evolution, both because the metaphorical term is interpreted in different ways in different situations, cultural contexts, historical moments, etc., but also because the reference point may change (e.g., a 'machine' today is different than in the past). Therefore, the use of metaphors requires that the characteristics implied by a particular metaphor are periodically reviewed to avoid possible misunderstandings or misrepresentations. Thirdly, sustainability priorities are not static but evolving in response to changing events and circumstances. This necessitates flexibility and precludes the existence of a definitive city metaphor to guide urban sustainability. Finally, working with metaphors can be 'messy', with terms that overlap and evolve, and with implied rather than explicit meanings. Consequently, it should be noted that our argument emphasizes the *heuristic* value of metaphors; they should not be taken as a replacement for the rigorous development of more specific concepts and models to analyze and describe urban phenomena. Awareness of these four pitfalls can help to ensure the kind of productive use of metaphors that we have argued for throughout this article, and thereby spur comprehensive, transdisciplinary efforts to strengthen global urban sustainability.

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