The Role of Social Innovations in a Revised Urban Metabolism Concept Framed by Sustainable Development Paradigms

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Synopsis

This paper presents the outputs of the research focused on a revision of urban metabolism conceptual framework, and a suggestion for a new approach considering social innovations as a key component shaping and redirecting metabolic processes and determining a city's sustainability.

1. Introduction

This article is focused on the role of social innovations in a revised urban metabolism concept. Urban metabolism is a concept utilized for quantifying energy and material consumption and tracing use patterns in urban environments (Pincetl et al. 2012, p. 193). This concept emerged in the mid-sixties when Wholman (1965) compared urban processes of material, energy and water transformation to those occurring in metabolisms of living organisms. Since its first emergence, the emphasis has been mainly placed on the efficiency with which resources are used, and the theory of urban metabolism has not been widely developed (Golubiewski 2012). The vagueness of the concept and lack of studies, which could provide a comprehensive quantification of urban metabolism, (Minx et al. 2011) resulted in urban metabolism failing to become a widely applicable system-based approach.
Since the last decade, many authors (Newman 2008; Minx et al. 2010; Goonetilleke et al. 2011; Pincetl 2012, Pincetl et al. 2012) continue to struggle to expand the concept, and define missing components which can transform the urban metabolism concept into a widely applicable system-based approach. In their scholarly articles they outline various urban drivers and factors which need to be considered as lifestyles (Minx et al. 2010), knowledge, information, technology, culture (Goonetilleke et al. 2011), and cultural priorities (Newman 2008). Scholars also highlight site-specific impacts on the character of urban metabolism and its correlation to locations, activities, or people (Pincetl et al. 2012). This article focuses on social innovations which utilize information, technology (Mulgan 2006), and spared knowledge via social networks, and shape cultural priorities and needs as their development and character determine characteristics of a respective community. Social innovations also characterize the lifestyle of a specific community because they are "generated by a social movement, defined as a group of actors sharing the same conditions, interests, visions, objectives or ideas, who are determined to undertake one or more actions designed to tackle some sort of social need" (Oliveira & Breda-Vázquez 2012, p. 524).

By the end of 2008, increasing urbanization achieved its magical milestone with more than a half of world's populations living in urban areas. More than ever before cities are becoming key habitats for humans and thus also placing increasing pressure on the environment, resources, and energy demands. A better understanding of the processes within the city system can reflect the interlinkages between the different drivers of urbanization, arising pressures and impacts, and can identify appropriate response measures (Minx et al., 2010). Negative impacts bounded with expanded human activities necessitates new planning approaches which may mitigate the impact and deliver sustainable development. Pincetl et al. (2012) advocate that expanded urban metabolism can address these negative impacts and outline possible pathways to sustain the quality of life for humans without permanently exhausting planetary resources or altering the planetary dynamics that support civilization.

Urban metabolism, when utilized as a system-based approach to understand urban metabolic processes and impacts, has the potential to integrate sustainable development measures into the management framework for urban development and growth. Goonetilleke et al. (2011) perceive the integration and adaptation of sustainable development into the management framework for urban growth as one of the most critical challenges facing modern urban settlements. Sustainable development paradigms also represent a framework for the research within this article.

The aim of this article is to challenge the urban metabolism concept and outline possible paths for its further extensions, which can overcome the inconsistencies in the theory and allow the concept to be utilized as a widely applicable system-based approach to understand urban metabolic processes. The key research question addressed is how social innovation determines and shapes "technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" (Kennedy et al. 2007, p. 44). This article is limited to a generally applicable theoretical background for further studies and experiments regarding the interplay between social innovations and material, and energy flows in urban metabolism. The methodology was based on a wide literature review utilizing comparative methods. This article is structured into five sections and a conclusion. The first section describes the current state of the urban metabolism concept, knowledge gaps, and looking closer at the ecosystem perspective. The second section familiarizes the reader with the nature of social innovations, which are exhaustively linked to the concept of urban metabolism in the third section. The fourth section relates the findings to sustainable urban metabolism and demonstrates them with numerous examples. The following discussion is summarizing the results in relation to the research objectives and discusses directions or opportunities for implementation of the findings.

2. Urban Metabolism Concept

Urban metabolism (UM) constitutes a concept addressing challenges associated with energy and material consumption in urban areas which focuses on accounting material and energy inputs and outputs into cities. Based on this concept, which emerged almost half a century ago, researchers have been struggling to develop a better understanding of energy and material flows in urban areas, and between them and the surrounding environment, with a special focus on their environmental impacts. Kennedy et al. (2007, p.44) defined UM as "the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste". Since the late twentieth century, output measures from UM analyses have been utilized for indicating urban sustainability and livability. This analysis provides a metaphorical framework within which we can examine the interactions of natural-human systems, and also provides a basis upon which to consider sustainability implications (Pincetl et al. 2012).

Despite its various possible applications UM has never been widely utilized in practice. Only a few UM studies exist, and none give more than a cursory explanation and justification of the analogy (Golubiewski 2012). There are numerous inconsistencies and unanswered questions raised by various authors. They argue (Minx et al. 2010; Golubiewski 2012; Pincetl et al. 2012) that further expansion of the concept necessitates a more interdisciplinary approach, which can better face challenges rising from such a complex system of a city. There is also a knowledge gap in understanding how site-specific issues impact sustainability measures for energy and material flows determining urban sustainability. Pincetl et al. (2012) pointed out that UM analysis necessitates matching energy and waste flows to land uses and social-demographic variables, in evaluation of the socioeconomic and policy drivers that govern the flows and patterns. There are insufficient studies explaining which components determine a distinct metabolism of a respective city, and how these specifics should be taken into account in the analytical and regulatory processes. Minx et al. (2010) pointed out that existing studies provide very little information in terms of the amount of resources extracted or the amount of pollution generated, and how this might change aspects of environmental quality, or how this might relate to basic concepts of environmental sustainability. Insufficient attention has been paid to how changes in the metabolism modify spatial and functional structure of complex and dynamic urban areas, how to manage these changes, and what the drivers of these changes are.

2.1 Ecosystem Perspective

Some authors (Marshall 2009; Pataki 2010; Golubiewski 2012) argue that the analogies described by Wholman (1965) and his followers (Huang and Hsu 2003; Sahely et al. 2003) fail in many dimensions, arguing instead that the metabolic flows of a city should be compared to the processes in an ecosystem rather than those in an organic body. Marshall (2009) suggests that a city is a complex, dynamic, collective entity: a super-unit, made up of components that are themselves units, rather than a corporate unit composing sub-units. He emphasizes the distinction between central intelligence characterizing living organisms and collective or distributed intelligence typical for ecosystems. Whereas an organism is a single individual, an ecosystem encompasses a complex assemblage of multiple individuals located within their environment (Golubiewski 2012), who do not rigorously rely on an overall decision-making executive. Unlike organisms, a city has competing as well as cooperating components, which often behave in a self-interested and selfish way regardless of the interests of a whole (Marshall 2009). An ecosystem is not equivalent to an organism because it is not under direct genetic control (Patten and Odum 1981), and all its components, their functions and unchangeable layout are not predicted before its genesis. Rather, they emerge, develop and cease to exist during one lifetime. Ecosystems are understood as complex systems which are continuously evolving and changing, though this change is at times either slow and gradual, or large and rapid (Biggs et al. 2010). Ecological succession does not operate unidirectionally toward a predetermined climax community and thus the ecosystem does not have a predetermined structure or morphology (Golubiewski 2012). Therefore, Biggs et al. (2010) suggest shifting the focus of ecosystem management away from attempting to maintain ecosystems in some fixed optimal state and instead focusing on guiding ecological change along desirable trajectories.

Buildings, people or infrastructure are components of a more comprehensive system tied together by tangible and intangible bonds (Marshall 2009). Positioning in the city determines the performance of each component and its further development or decline, depending on the mutual interaction between a component and the superior system. A distinguishing feature of complex systems is that they are defined more by the interactions among their constituent parts than by the parts themselves (Biggs et al. 2010). Compared to a city, urban components interact via metabolic flows of energy, materials producing various technical and socio-economic processes represented by UM. Character and extent of these processes determine the transformative change of an urban component. The existence of these processes depends not only on the presence of energy or materials in the system, but on the inclusion of innovations, another element which can impact character, extent and direction. Innovations form the development of an urban component, and their presence and attributes determine the extent and character of needs for certain material and energy flows. Compared to an ecosystem, Biggs et al. (2010) also suggest a social-innovation framework for the analysis of transformative change in ecosystem management because it not only describes processes of change, but also emphasizes the factors and leverage points that may foster their emergence.

3. Nature of Social Innovations

Innovation is a concept studied in many disciplinary contexts, leading to a multiplicity of definitions, including psychological, sociological, and economic ones (Wineman et al. 2009). Innovation differs from invention in that it does not only refer to the creation of new ideas or products, but also to the processes of diffusion or adoption that make promising ideas useful in meeting social needs (Biggs et al. 2010). Social innovation refers to innovative activities and services that are motivated by the goal of meeting a social need and that are predominantly diffused through organizations whose primary purposes are social (Mulgan 2006). They mean the application of creativity to social purposes (Moulaert and Nussbaumer 2005; Mulgan 2006, Oliveira & Breda-Vázquez 2012), introducing changes in a social landscape (Moulaert et al. 2005). Innovations have to cross the chasm as they pass from being promising pilot ideas to becoming mainstream products or services (Mulgan 2006). "Every successful social innovator or movement has succeeded because it has planted the seeds of an idea into many minds" (Mulgan 2006, p. 149).

Social innovations are not easily replicable; it may take decades to create the environmental conditions for growth, and the organizational challenges are no less severe (Mulgan 2006). Places and spaces are highly relevant for the emergence and thriving of social innovations because they are simultaneously dependent on both path and context. (Oliveira & Breda-Vázquez 2012). These dependencies stem from the nature of urban system from which they emerge, as each system has its own specificities, including the mix of resource use and social organization, governance and position in larger systems (Pincetl et al. 2012), quality of communications (Keller 2008), system scale and diversity of actors (Drewe et al. 2008). These factors may contribute decisively, while diversity of actors is considered a key factor in sustaining social innovations and promoting their diffusion across different territories, policy sectors and segments of society (Oliveira & Breda-Vázquez 2012).

4. The role of social innovations in urban metabolism

There is an assumption that different cities have different metabolic processes even though they may use approximately the same amounts of energy and materials because they depend largely on site-specific conditions (Minx et al. 2010; Pincetl et al. 2012). In the last decade many authors (Gandy 2004; Kennedy et al. 2007, Newman, 2008; Minx et al. 2010; Goonetilleke et al. 2011; Pincetl et al. 2012; Pincetl 2012) are searching for factors and drivers which are responsible for these variations. Kennedy et al. (2007) claim that the metabolism of cities should be analyzed in terms of four fundamental flows or cycles (water, materials, energy, and nutrients) and differences in the cycles may be expected between cities due to age, stage of development (i.e., available technologies), and cultural factors. Minx et al. (2010) found that metabolic flows are equally shaped by drivers such as land-use planning and infrastructure decisions or the economic role of the city under consideration as well as the lifestyles of its residents. Goonetilleke et al. (2011) define intangible inputs as knowledge, information, technology, values and culture, which are included within the integrated UM framework. Pincetl et al. (2012) suggest that UM analysis, to be effective, also requires consideration of variables such as demography, economy, health, mobility/accessibility, equity, community quality, policies and regulations, employment, and education. Furthermore they pointed out that interdisciplinary collaboration is necessary for matching energy and waste flows to land uses and social-demographic variables, in evaluation of the socioeconomic and policy drivers that govern the flows and patterns.

In this article it is suggested that examination of amount, generation, and character of social innovation also play an important role in expanding the UM concept. The aforementioned conditions for growth and development of social innovations share many common features with the factors and drivers expanding the UM concept as characterized by UM researchers.

They are both context-dependent and interplay in the socio-cultural development dimension. The character and rate of generation and implementation of social innovations shape such factors as lifestyle, stage of development, demography, economy, mobility, accessibility, values and culture.
For example, the growth of metabolic flows is due to the increase in urban population, but even more to the rising per capita demand of citizens for floor space, goods, leisure activities, etc. (Kennedy et al. 2007). It was proven that a reduction in household size and dwelling occupancy are a more important driver of CO_2 emissions than population growth (Minx et al. 2010). Drivers for new needs in terms of, for example, floor space, goods or leisure activities are closely tied to new possibilities (Mulgan 2006) arranged by innovations. Social innovations are introducing changes in a social landscape which are becoming mainstream, gradually forming urban lifestyles.

> Much of what we now take for granted in social life began as radical innovation. A century ago, few believed that ordinary people could be trusted to drive cars at high speed, the idea of a national health service freely available was seen as absurdly utopian, the concept of “kindergarten” was still considered revolutionary, and only one country had given women the vote. Yet in the interim, these and many other social innovations have progressed from the margins to the mainstream (Mulgan 2006, p. 145).

In the western world, the ideas of individualism boosted new activities which were introduced and disseminated via social innovations. They shifted the traditional values of family life to those of self-reliance, self-presentation, and self-realization with tremendous effects on urban metabolic flows. Large family households gradually became obsolete and people began investing their time and effort into securing their self-reliance rather than raising many children. This transformation brought changes in terms of demography, represented by the decreased fertility rate and also affected city growth in the expansion of the areas needed for housing development. The implementation of social innovations such as kindergarten, work-free Saturdays, or various technological innovations like the electric washing machine, dish washer, and stove supplied even more time for self-presentation, and self-realization. New activities and opportunities now appeared, and were reflected by changes and creations of new metabolic flows. The use of airplanes for summer holidays, or self-organized weekend trips using a passenger car became standard for most western households. Inventions such as the World Wide Web, cell phones or internet shopping do not cause recognizable change in organizations of urban metabolic flows until they undergo the processes of diffusion and adoption involving the masses and thus become innovations. In the field of communication and transport, innovations are broadly extending accessibility of various materials, nutrients and energies, causing modern cities to no longer rely on their hinterlands; rather, they participate in continental and global trading networks (Kennedy et al. 2007).

In very early stages of the process of innovation, the presence of creative people is necessary because they come up with new ideas that can possibly become innovations (Mulgan 2006, Oliveira & Breda-Vázquez 2012). These people, including artists, writers, scientists, entertainers, actors, and designers, make up the core of the ‘creative class’ and they tend to cluster in certain places, not only for economic but also for lifestyle reasons (Oliveira & Breda-Vázquez 2012). They seem to be attracted to locations that offer diversity, authenticity, tolerance and inclusiveness, the so-called ‘soft location factors’ (ibid.). Compared to business innovation models in which bigger organizations have more 'absorptive capacity' to learn and evolve innovations, (Mulgan 2006) large cities are also often found to be the places which give birth to massive social changes. They can provide a pooled market for knowledge workers, more efficient suppliers to the industry (Teirlinck and Spithoven 2008) and also attract the creative class due to their soft location factors. The generated social changes are gradually transferred from the city of origin not only to similar cities which keep active exchanges of human capital, knowledge, and innovations, but also between the city and its hinterland. This transfer can be observed in the example of backyard farming fading as the result of lifestyle change and eased accessibility of imported food. Initially it vanished from the urban outskirts and continued further to the hinterlands which were increasingly colonized by urban population spreading social innovation originally evolved in urban areas. This social innovation transfer significantly transformed nutritive metabolic flows, not only of the hinterland itself, but also of the city depending on it.

5. Sustainable urban metabolism

Urban metabolism provides a metaphorical framework to examine the interactions of natural-human systems and provides a basis upon which to consider sustainability implications (Pincetl et al. 2012).

> The decision to concentrate on materials is based on the fact that there are reliable metrics for the assessment of urban material flows and stocks and that materials and substances are crucial for the sustainability of a city in terms of functioning resource availability, and environmental protection (Kennedy et al. 2007, p. 11).

Since the late 1980s 'sustainable development' and 'sustainability' have gradually become a main objective of the majority urban planning frameworks even though the concept of sustainable development and sustainability itself is still vague and undefined (Goonetilleke et al. 2011). Additionally, UM researchers have not achieved a stabilized consensus on what measures and characteristics represent its sustainable state. Nevertheless, the current set of practices defined by sustainable development research still represents the most reliable framework for UM. Minx et al. (2010) highlighted that the standard UM concept only provides information on environmental pressures in terms of the amount of resources extracted or the amount of pollution generated, but on the other hand it provides little information in terms of how this might change aspects of environmental quality or how this might relate to basic concepts of environmental sustainability. Pincetl et al. (2012) suggest that the sustainable city implies an urban region for which the inflows of materials and energy and the disposal of wastes do not exceed the capacity of its hinterlands. Newman (1999) stated that the best way to ensure that there are reductions in impact is to reduce the resource inputs. Kennedy at al. (2007) further pointed out that understanding the changes to storage processes—water in urban aquifers, heat stored in urban canopy layers, toxic materials in the building stock, and nutrients within urban waste dumps in some cities- may be as important as reducing the sheer magnitudes of inputs and outputs.

Resource depletion and energy deficiency are shifting the focus on other components of urban metabolism which can partially subsidize material and energy flows. This article suggests that innovations and their management have the ability to transform or redirect material, energy and nutritive urban metabolic flows. Minx at al. (2010) presented how three different approaches to content urban energy demands can impact the quality of the environment and thus determine urban sustainability.

> For example, to meet increased urban energy demands, a city can build a new power plant increasing local air pollution. This might have detrimental health effects for at least some of the urban population and therefore diminish quality of life in the city. Alternatively, it can import the additional energy from elsewhere. In this case, whilst the metabolism of the city grows, urban quality would not be affected in the city of consideration (but potentially elsewhere). However, the global environmental effects could potentially be negative (even though not necessarily). A third alternative could be the replacement of an old, small inefficient power plant with a new, bigger and highly efficient one on the city's

territory, which provides more usable energy with a smaller pollution output. In this case depending on the degree of efficiency improvements and the level of additional energy demands, the metabolic change could even decrease local air pollution and improve urban quality.

In these three examples it can be easily observable how technological innovation offers the most environmentally friendly solution. Many more examples can be found where innovations shape, redirect or bring to the end various urban metabolic flows. Social innovations like community wind farms or zero-carbon housing developments are bringing considerable changes to the environmental impacts of per capita energy demands. Consideration of social innovation character and rate of generation can increase the accuracy of UM analysis and also outline sharper contours of its further development.

Goonetilleke et al. (2011) argues that waste should be viewed as a resource, to be used 'fit for purpose' rather than to be disposed as expeditiously as possible. Today's stock is tomorrow's waste, and can serve as a future resource because of the time gap between input and output: in a growing economy, the future amount of wastes will be much larger than today's (Brunner 2007). Ecological friendly innovation like recycling can turn the state of UM from a linear one to a more circular one in which resources are utilized multiple times and thus lower inputs are needed. Social innovation stimulation and promotion can be crucial, as the social change produced depends on how many people are being persuaded to abandon old habits (Mulgan 2006). Reduced dependency on external supplies of resources would increase the stability, diversity and resilience of the urban ecosystem (Golubiewski 2012).

6. Discussion

The aim of this article was to outline possible paths for further extensions of the concept of urban metabolism, which can overcome the inconsistencies in the theory and describe how social innovation determines and shapes technical and socio-economic processes that occur in cities. The research aiming to answer the key research question was limited to a generally applicable theoretical background for further studies and experiments regarding social innovations in UM.

To our knowledge, it is the first study that examines the role of social innovations in the UM concept. This article critically assessed the current state of the matter and outlined new approaches which expand the concept, and defined missing components which can possibly transform the UM concept into a widely applicable system-based approach. Better understanding of the processes in UM can reflect the interlinkages between the different drivers of urbanization, arising pressures and impacts, and identify appropriate response measures (Minx et al. 2010). Expanded UM has the potential to integrate sustainable development measures into the management framework for urban development and growth.

Social innovation determines and shapes technical and socio-economic processes that occur in cities because they form the development of an urban component, and their presence and attributes determine the extent and character of needs for certain material and energy flows. The character, and rate of generation and implementation of social innovations shape factors such as lifestyle, stage of development, demography, economy, mobility, accessibility, values and culture which were previously found to have an impact on UM. Social innovations significantly transform metabolic flows not only of the city of their origin, but also metabolic flows of its hinterland and similar cities with which it maintains an active exchange of human capital, innovation and knowledge. Innovations and their management have the ability to transform or redirect material, energy and nutritive urban metabolic flows and bring considerable changes in environmental impacts. They can turn the state of UM from a linear one to a more circular one in which resources are utilized multiple times and thus lower inputs are needed.

Integration and implementation of the UM concept into planning institutional framework is perceived as a conditioning prerequisite for the utilization of its ideas in practice. Such a framework should provide a platform whereby different disciplines can appreciate, absorb and learn from other areas, and should have the flexibility to adapt to a range of dynamic scenarios of defined elements in the expanded UM framework (Goonetilleke et al. 2011). It should secure a balance between complementary and contradictory social, economic and environmental goals via negotiation, compromise and integration of technical designed oriented knowledge (ibid.).

Territorially rooted institutional context made up of formal and informal rules, values and practices is extremely hard to reproduce, but plays a crucial role in respect to social innovation adaptation and diffusion (Oliveira & Breda-Vázquez 2012). Organizations and government institutions should take the managerial role over the processes, and provide appropriate supporting mechanisms as some social innovations may fit better with diverse contexts than others (ibid.). On the other hand, regulating mechanisms are also necessary because not all social innovations in any extent support suitable UM. The supporting mechanisms have to be focused on creating an appropriate environment securing emergence of innovations, because social innovation cannot be directly planned and produced; it can only be stimulated by creating an environment conducive to the emergence of innovation (Biggs et al. 2010). The environment has to provide networks where apparently unrelated methods and ideas can be used together (Mulgan 2006).

7. Conclusion

Innovations need to be interpreted as new dimensions in the urban metabolism concept. Constantly accelerating innovations determine the orientation and also the existence of most urban processes, representing the key elements steering urban development and sustainability. Better understanding of the development tendencies and interdependences between material, energy, nutritive, and innovation flows can deliver a more comprehensive assessment of viability and efficiency of respective planned managerial interventions. The responses of various urban agents anchored in a city's institutional framework to innovations, in the context of socio-cultural specifics, co-determine urban metabolism processes. Further research will be needed to examine the tasks of urban metabolism management and to develop a consistent methodology utilizing the findings presented in this article.

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