Sustainability and urban settlements: urban metabolism as a framework for achieving sustainable development

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Abstract: Urban settlements, with their role as economic and governance nerve centres, are rapidly expanding in size and in consumption of resources, and consequently have significant impacts on the environment. The transition to an 'eco-city' - an urban settlement that adopts the goals and principles in the urban metabolism model - needs to occur to meet the challenges posed by a multitude of pressures including population growth, climate change and resource depletion. Thus, the adoption and integration of 'sustainable development' into the management of urban growth is one of the most critical governance issues for urban settlements. A framework in which sustainable development can be achieved is through the lenses of the established theoretical concept of 'urban metabolism'. The key facet of the proposed 'Integrated Urban Metabolism Framework' is the provision of a platform whereby different fields can appreciate, absorb and learn from other areas, to increase the understanding of where each and every one of the pieces fit together in order to create a larger, holistic approach to the currently stagnant problem of unsustainable development.

Keywords: Sustainable urban settlements; sustainable development; urban metabolism; integrated urban metabolism framework

Introduction

While the notion of 'sustainable development' and 'sustainability' has generally been the accepted objective in which governments and communities alike should work towards, the concept itself is still vague and undefined. The concept is broadly and most popularly implied as actions that should not harm future generations' abilities to meet their own needs (WCED, 1987). However, sustainability also needs to include concepts of holistic planning encompassing all facets of resilient development such as social, economic and environmental factors (Milman & Short, 2008). In this context, the concept itself is still highly contested and fuzzy, with numerous of different definitions of sustainability. Although vague, sustainability is a useful concept, compelling everyone - from the decision makers, the managers to the public - to consider where development is taking us environmentally, economically and socially. Despite the inability to agree on a set definition, most analysts agree that urban areas have negative bearings well beyond their own boundaries, bringing with them adverse social and environmental impacts (McManus & Haughton, 2006). Urban settlements in particular, play a significant role in improving the quality of life by being hubs of economic and cultural activities, but they also need to ensure that these roles are maintained and re-generated through the revitalisation of current systems (Keirstead & Leach, 2007).

Urban metabolism

Urban settlements, with their primary role as economic and governance nerve centres, are increasingly expanding in size and in resource consumption, and consequently have significant impacts on the environment (Haughton & Hunter, 1994). A transition to an 'eco-city' – an urban settlement in which Newman (2008) describes as urban areas which adopt the goals and principles of the urban metabolism model – needs to occur in the immediate future due to the compounding of pressures of population growth, climate change, resource depletion, environmental pollution and habitat degradation, which currently pose a significant threat to our way of life and the political and social stability of our planet.

Thus, the adoption and integration of 'sustainable development' into the management framework for urban growth is one of the most critical challenges facing modern urban settlements. In order for true sustainability to be achieved, there needs to be consideration of not only economic factors, but also social issues such as intra and inter-generational equity as well as poverty in the context of the broader society, as urban settlements often do not exist in isolation and have impacts on its surrounding areas (Haughton & Hunter, 1994; Schmid, 2004; Stimson et al., 1999).

The achievement of sustainable urban settlements, however, requires realisation that current linear, open looped processes should be recognised as unsustainable in the long term, lacks resilience and cannot be maintained without significant resource inputs, which are becoming increasingly scarce. It is vital that modern society begin to incorporate sustainable, close looped features into resource intensive, but 'invisible' to the general public, facilities and services that keep settlements running (Brunner, 2007). Urban settlements are mostly dependent on the surrounding hinterland for, resource supply and for the disposal of wastes (Brunner, 2007). The hinterland absorbs a disproportionate amount of waste in order to maintain the functioning of urban areas and is seen as 'bottomless pits' by the city/urban dweller.

The established theoretical concept of 'urban metabolism' presents a framework through which sustainable development can be achieved. The concept of urban metabolism originated from Wolman's (1965) seminal paper on the metabolism of cities, whereby the inputs of resources and outputs of waste for the successful survival of cities was considered to mimic the manner in which a body functions. Similar to a living organism, urban settlements receive resource inputs such as human capital, raw materials and water and energy, which are then transformed into goods, services and other vital elements that support the needs of the population, and in the process generate solid, liquid and gaseous wastes which needs to be disposed appropriately (Wolman, 1965). This process is illustrated in Figure 1 below. The management of the various waste streams and their potential for imposing adverse impacts on the human and natural ecosystem poses its own unique set of challenges.

Utilising the Laws of Thermodynamics, the concept of urban metabolism works on the basis that the amount of waste generated is proportional to the amount of resources that is input, and, therefore, a balance sheet of resource consumption and waste production is created (Newman, 1999). The urban metabolism framework is one way in which the balance between complementary and contradictory social, economic and environmental goals can be achieved through negotiation, compromise and integration of technical designed oriented knowledge. Application of an urban metabolism framework to measure and to analyse the metabolic processes, identification of the efficiencies of these processes and inherent constraints, as well as the implementation of this framework requires a wide range of knowledge and necessitates skills and multi-disciplinary expertise (Stimson et al., 1999).

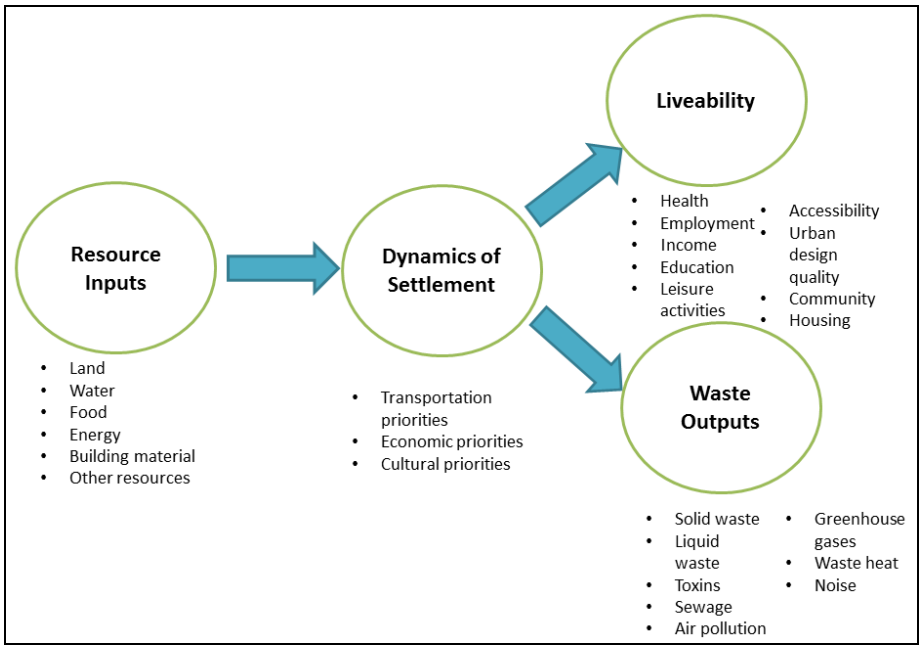

Figure 1. Extension of the urban metabolism model to urban settlements (adapted from Newman, 2008)

Newman (1999) argues that a transition to a more sustainable approach to urban settlement development needs to occur as a matter of priority due to the instability arising from the impacts of current development activities, the long term unsustainability of current approaches and the misleading nature of cost-benefit analysis based solely on monetary metrics which can stifle innovations in sustainability. Current methods in delivering key infrastructure, systems and services are

neither sustainable nor resilient, and when combined with resource scarcity and the impacts of climate change, hurtles society into an uncertain future fraught with instability and potential conflict.

The 21st century marks an important watershed in urban settlements with the global population becoming predominantly urban. Urban settlements must, therefore, have the in-built flexibility to adapt and embrace change and innovation to cater to the needs and aspirations of its burgeoning population and at the same time to ensure that it is not 'polluting its own nest' in terms of waste generation and resource consumption. Consequently, urban settlements will need to be at the forefront of incorporating sustainability, not only into infrastructure but also into the behaviour and consumption of its citizens – essentially integrated into its social and economic fabric. The Integrated Urban Metabolism Framework, developed by the authors, proposes that to make the paradigm shift to a resilient and sustainable development, the three key features that support the wellbeing of urban settlements and by implication its people must be looked at with equal weightings, as illustrated in Figure 2 below.

Urban settlements that are specifically tailored to encompass the fundamental human needs such as quality of life and place and connectivity, with housing that is affordable and climate adaptive, supported by sustainable infrastructure such as water, sanitation, transport and energy forms a resilient and sustainable development. Though liveability is a critical aspect of quality of life and place, it is only one aspect of the equation that contains a number of other equally important factors that needs to be considered; Australia, while considered one of the most liveable places in the world, consumes a large amount of resources on a per capita basis that is simply not sustainable (Newman, 2008). Additionally, on a per capita basis, Australia has one of the world's highest rates of greenhouse gas emissions, which further highlights an unsustainable life style. The main goal of an urban settlement should be that of resilience that is achieved through sustainable development, which according to the Australian Government's Ecologically Sustainable Development Steering Committee is to improve the total quality of life, both now and in the future, in ways that maintain the ecological process on which life depends (Ecologically Sustainable Development Steering Committee, 1992).

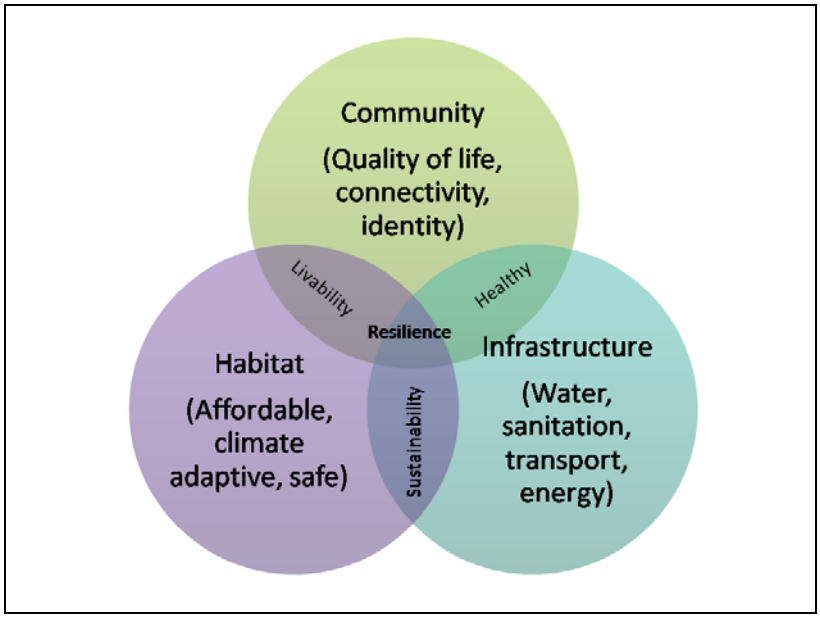

Figure2. Components of a resilient and sustainable development of urban settlements

The integrated urban metabolism framework

While a plethora of studies have been conducted on ways and means in which sustainable development of urban settlements can be achieved, a large number of research studies have focussed only on just one of element of the workings of an urban settlement – essentially mono-disciplinary investigations into a multidisciplinary frame of reference. Investigations which are integrated, where a diversity of knowledge inputs and outcomes from scientific studies from different disciplines including, but not limited to engineering, planning, design, architecture, social sciences are assimilated to develop a holistic framework for sustainable development, is still lacking. The key element to an integrated urban metabolism framework is the creation of a platform whereby different disciplines can appreciate, absorb and learn from other areas, to enhance the understanding of where each and

every one of the component parts fit together in order to create an approach to achieve sustainable development, which is holistic and integrated. It should have the flexibility to adapt to a range of dynamic scenarios such as population growth, climate change and resource depletion and other attendant issues.

Utilising the concept of transitions discussed above, we propose an innovative framework – The Integrated Urban Metabolism Framework – that examines the process in which resilient and sustainable development can be achieved. Under the much discussed pressures of climate change, population growth, economic constraints and resource scarcity, urban settlements need to receive different inputs that allow them to function smoothly to cater to the needs of the population. Present urban settlements do not have this process as a closed loop; invariably most current urban areas simply regard waste and emissions as an output that is returned to the environment, usually in a state of decay. Future urban settlements must incorporate technologies and methods that allow for the recycling and collection of these elements for recycling and reuse. Waste should be viewed as a resource, to be used 'fit for purpose' rather than to be disposed as expeditiously as possible. For example, sewage can be used for nutrient recovery for use in urban agriculture. These concepts are not new, but they have failed to gain traction in the mainstream due to the lack of recognition, adoption and resourcing. Figure 3 below depicts the proposed framework.

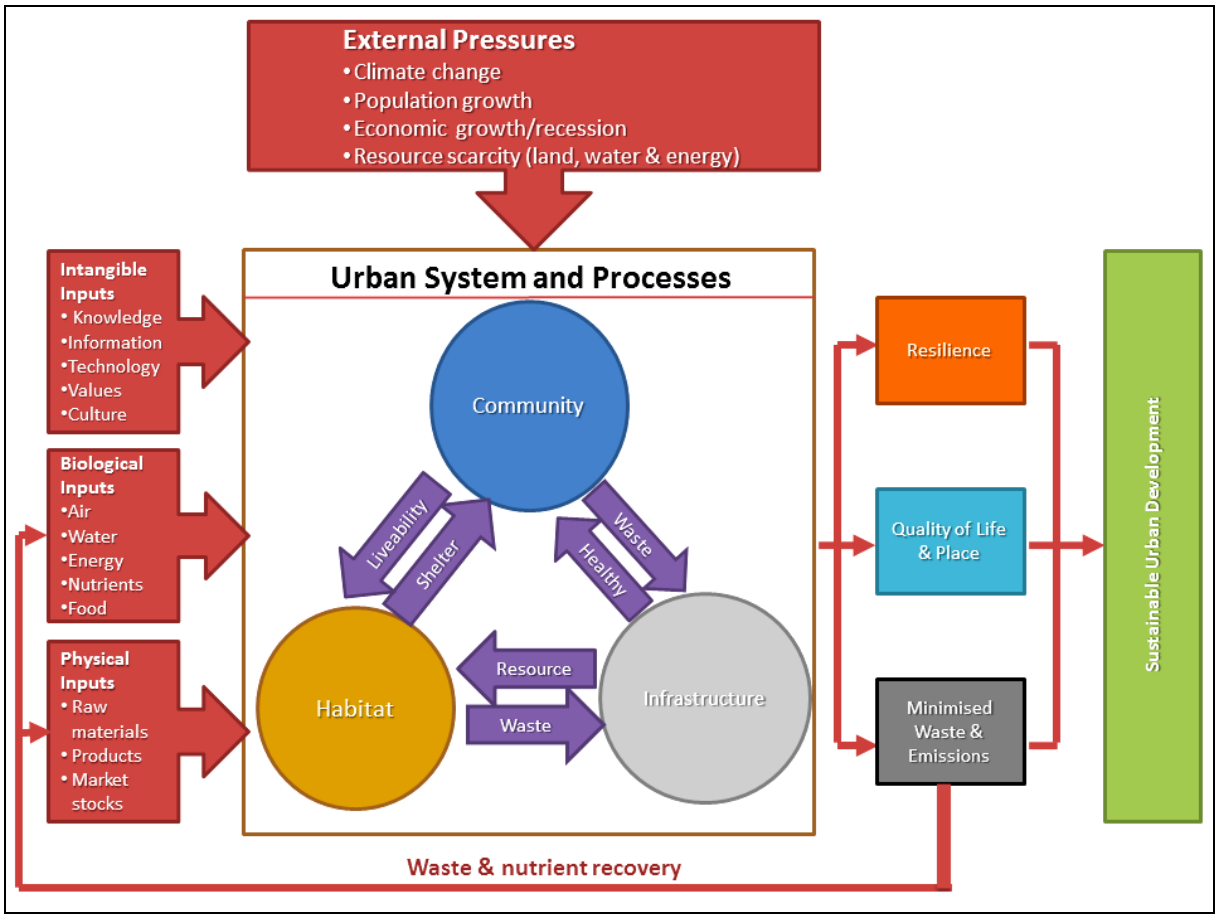

Figure 3. The Integrated Urban Metabolism Framework

Constrained by the global pressures of population growth, climate change and both carbon and resource constraints, urban settlements function by having biological, physical and other intangible inputs. Through urban systems and processes, the three main pillars of an urban settlement – community, habitat and infrastructure – react upon each other to ensure the satisfactory functioning of society where aspirational outputs should include resilience, quality of life and place with minimised, or even zero waste and emissions. However, this is rarely the case for most urban settlements. While it is not always possible to eliminate 100% of emissions, loads can be reduced through lowered resource inputs and/or increased efficiencies and innovations in urban processes. Waste and emissions can then be harvested to be reused either as new resources, or in other forms so as to augment 'virgin' resources needed to support the smooth running of urban settlements. This

closed loop framework mimics the eco-system model, whereby waste is minimised and reused as much as possible. Sustainable development is therefore not only about the reduction of resource inputs either due to more efficient use and the minimisation of waste and emissions, it is also about increasing the liveability of urban areas with improved quality of life and place, as well as a resilience towards foreseen and unforeseen external pressures.

Implementation and the way forward

An inter-disciplinary approach: An integrated, science based understanding of the dynamics, growth, and organisation of urban areas needs to be established. While urban settlements may be the source of many environmental, social and economic problems, in conjunction they are also hubs of knowledge, creativity and wealth, and are able to supply solutions to these problems (Battencourt & West, 2010). Establishment of dialogue, through multi-disciplinary teams will aid in the establishment of a learning loop that allows each field to learn from each other. Recognition of the technical definitions of the terms that are used, such as 'sustainable development', 'resilience' and 'quality of life and place' would constitute an initial structure that could facilitate dialogue between different disciplines (Pickett et al., 2004). This study loop is integral because urban systems are inherently complex, have interrelated infrastructure, social and economic elements, and a wide range of skills and technical knowledge is needed to ensure that they are understood in conjunction, and not in isolation (Battencourt & West, 2010). As Battencourt and West (2010) warn, disaggregated approaches can lead to ineffective or even disastrous policy consequences, pointing towards the examples of the declining industrial urban settlements of many parts of the world.

Thus, the Integrated Urban Metabolism Framework is dependent on a range of disciplinary areas to enable the function and the implementation of such a framework. For example, engineers are required to undertake material flow analyses and ecologists are needed to conduct research that target links between the role of humans, the ecosystem and resilience. Policy makers, in particular, have much to take from this; a scientific and mathematical understanding of urban metabolism dynamics, while not directly informing policies, is still able to be utilised to ensure a robust, resilient and sustainable growth of urban settlements, while targets and goals can be converted into actions and policies that can be measured, therefore, guiding policies for the creation of better solutions (Battencourt & West, 2010).

Adaptation to climate change, population growth and resource depletion driven impacts: When Wolman (1965) conceived the concept of urban metabolism, he was using it as an analogy to study water and air pollution in US cities. However, Kennedy et al. (2011) contend that the urban metabolism model are applied more widely, such as for sustainability indicators, urban greenhouse gas accounting, mathematical modelling for policy analysis as well as implications for urban design. The development of sustainability indicators has been one of the key areas of use of the urban metabolism framework. For example, the Australian State of the Environment report discusses this framework at length (State of the Environment Advisory Council, 1996; Newman, 1999).

It has been taken for granted that urban settlements will continue to grow economically unbounded by constraints. However, this is not the case in today's world. Battencourt and West (2010) note, that growth can only be sustained if major innovations and retrofitting is undertaken due to continuously diminishing resources. The urban settlement is a system, receiving resource inputs and through urban systems and processes and produces not only well-being and quality of life and place, but also waste and emissions. The primary issue remains the increasing resource inputs that are needed in order to maintain this well-being and quality of life and place while tackling the increasing waste and emissions (Newman, 1999). Continuous adaptation, especially due to the pressures of population growth and resource depletion as well as impacts of climate change, is vital if urban areas are to maintain and sustain the expected quality of life and place. The adaptation to climate change impacts is particularly important, as it relates to the resilience of urban areas. Queensland, Australia found out to her peril in January 2011 how unprepared she was to deal with sudden natural disasters due to many critical urban infrastructure systems not being resilient. Folke et al. (2004) define resilience as the capacity of a system to absorb disturbances and reorganise while undergoing change so as to retain essentially the same function, structure, identity and feedbacks. This concept of resilience is useful as it allows for the marriage of two of the key elements in urban development, which are ecosystem functions and social dynamics (Andersson, 2006).

Zero or minimisation of waste and emissions: Only so few urban settlements have a full assessment of their urban metabolism (Newman & Kenworthy, 1999). However, indicators of sustainability can be

constructed, and through this it is possible to locate areas to focus attention in order to reduce resource use. Newman (1999) points out that most urban settlements would be able to pin-point policies, areas and actions in order to reduce waste and emission outputs, but without proper measurements in which the Integrated Urban Metabolism Framework is able to provide, the true extent of the task at hand and the pace of progress cannot be systematically determined.

Further development and application directions: The conceptual structure of the Integrated Urban Metabolism Framework has recently been developed with the aim to establishing a platform for the creation of an interdisciplinary and holistic approach for the sustainable development of urban settlements. This framework is expected to provide a systematic approach to sustainable development and is expected to provide solutions to the currently stagnant problem of unsustainable nature of urban settlements. The framework is planned to be pilot tested in case studies in South East Queensland, Australia in order to further advance and operationalise the framework for it to become an effective and efficient tool in assessing material flow and channelling the sustainable development of urban settlements.

Conclusion

Urban settlements are the cradle of humanity's resilience, innovation and intelligence, but are also the source of many of current problems, from overpopulation to environmental degradation. It is, therefore, crucial that the dynamics and systems that allow urban settlements to function smoothly be understood from the viewpoint of all relevant disciplines. The proposed Integrated Urban Metabolism Framework presented in this paper understands that in order to achieve the still elusive sustainable development, there is a need to look at the functioning of urban areas holistically as opposed to the current piecemeal manner research, policies and plans are being conducted. With this interdisciplinary approach, the framework can be used for the building of sustainable, resilient urban areas that are flexible and dynamic with the ability to adapt to impacts of climate change, population growth and resource constraints.

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