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Urban fabrics and urban metabolism – from sustainable to regenerative cities

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ABSTRACT

This paper uses urban metabolism as a way to understand the sustainability of cities. It suggests that the city organism can reduce its metabolic footprint (resource inputs and waste outputs) whilst improving its livability. Like organisms, different cities have different metabolisms. This paper demonstrates that different parts of a city (walking, transit and automobile urban fabrics) also have different urban metabolisms. A detailed case study from the city of Perth, Australia, is used to demonstrate metabolic variations in different parts of the city. Understanding urban metabolism and the processes that drive it is the key to transitioning from ecologically extractive to sustainable cities. Through targeted improvements it is even possible for some elements of the city to become regenerative so that they restore parts of the degraded urban environment thus reversing damage to the biosphere.

1. Introduction

1.1. Aims and objectives

The objectives of this paper are twofold. The first objective is to demonstrate how different urban form and infrastructure (urban fabrics) play an important role in determining urban resource flows i.e., different urban fabrics have different urban metabolisms. While most early studies on urban metabolism tended to focus upon the whole city or city regions e.g., (Baccini, 1997; Kennedy et al., 2011; Newman et al., 1996; Warren-Rhodes and Koenig, 2001), the case study presented in this paper describes differences that have been observed in different parts of Perth, Australia – a medium sized city of two million people. We suggest a causal link between reductions of urban metabolism and the underlying urban fabric.

The second objective aims to apply this knowledge in a practical manner to help deliver a regenerative city. In this sense urban metabolism may be used as a design tool by city makers to optimize the efficiency of the underlying urban fabric, calibrate development to maximize regenerative design outcomes, and catalyze urban sustainability transitions. This is necessary because the present generation of the human population is facing unprecedented global grand challenges including rapid population growth, increasing consumption patterns, resource scarcity, climate change, biodiversity loss and social inequity (Bina et al., 2016) and cities can do more than just reduce their impact but can regenerate past impacts.

Recent work on the planetary boundaries framework (Rockström et al., 2009; Steffen et al., 2011, 2015) suggests that a failure to shift the trajectory of current environmental impact presents an existential risk to *homo sapiens*. In their assessment of planetary boundaries Steffen et al. (2015) suggest that policy, governance and business approaches to the two core planetary boundaries – climate change and biosphere integrity – need to change.

There have been numerous papers on the need to find a 'safe operating space' for human activity that lies within planetary boundaries (Costanza, 2008; Du Plessis and Brandon, 2014; Rockström, 2009; Rockström et al., 2009; Seitzinger et al., 2012). However, the justification to rapidly respond to these grand challenges has recently moved beyond an ethical reason to a political one. The ratification of two major international policies by most member states of the United Nations – the Sustainable Development Goals (SDGs) (United Nations General Assembly, 2015) and the Paris Agreement (United Nations, 2015a) put in place a global political mandate for change. While both of these policies outline clear targets or objectives to direct humanity away from a potential existential crisis caused by present unsustainable human activity, they do not offer the mechanisms for achieving the required shift.

This paper offers some potential solutions. It does this by demonstrating how the underlying urban fabric heavily influences urban metabolism. By better understanding this relationship, science can help inform urban decision-makers to deliver not just

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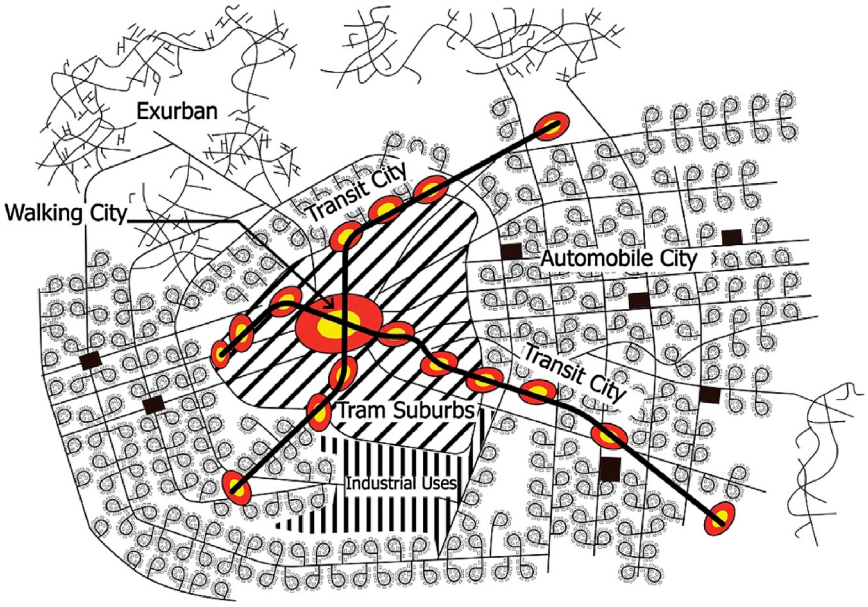

Fig. 1. Automobile urban fabric, transit urban fabric and walking urban fabric, a mixture of three urban fabric types of a typical city.
Source: Newman and Kenworthy, 2015

sustainable but regenerative built form that is capable of driving local and regional transitions that can seriously address planetary boundaries. If this can be done at scale, then a global network of regenerative cities has the potential to play a major role in this global challenge.

Cities present an opportunity because the human population is rapidly urbanizing. In 2014, 54% of the world's population were residing in cities and by 2050 this figure is expected to be close to 70% concentrating sustainable development challenges within cities" (United Nations Department of Economic and Social Affairs Population Division, 2014). Harnessing this wave of urbanization as a means for delivering sustainable human settlements could represent a major opportunity for reducing ecological footprint. Indeed the *New Urban Agenda* coming out of Habitat III in October 2016 calls for an urban paradigm shift that will "redress the way we plan, finance, develop, govern and manage cities and human settlements, recognizing sustainable urban and territorial development as essential to the achievement of sustainable development and prosperity for all". Actions to achieve this would include "integrated urban and territorial planning and design in order to optimize the spatial dimension of the urban form and to deliver the positive outcomes of urbanization" (United Nations, 2016, pp. 3–4). But to do so would require calibration and improvement of urban performance through ongoing urban metabolism assessment to ensure urban sustainability performance targets are met or exceeded so that cities can be a major force in reversing planetary boundary challenges.

Kennedy et al. (2011, p. 1968) describe the potential of the data rich urban metabolism for practical application to urban design and planning. Through the urban metabolism analysis presented in this paper we offer some conclusions that will be useful to urban planners to understand where the best leverage points may be to help provide infrastructure that best supports citizen efforts to reduce and then reverse the ecological footprint of cities.

The paper offers a brief overview of the historic origins of cities that have led to the widespread creation of unsustainable urban form, it describes our approach to urban metabolism and the use of regenerative design as an aspirational target for delivering the regenerative city, before presenting an urban metabolism analysis prepared on Perth. This is the first study we are aware of that has been developed to demonstrate the variations in urban metabolism across different urban fabrics within the same city and can be used to show the kind of dramatic changes that cities need to address.

1.2. Background

1.2.1. Historic origins of cities

Over the last 10,000 years since the advent of agriculture, *homo sapiens* transitioned from nomadic hunter-gatherer to farming settlements (Zvelebil, 2009). This transition marks a shift from living within an ecosystem to extraction from an external ecosystem to support human life. The agglomeration benefits for culture and trade increase with the size of the settlement (Florida, 2002; Glaeser, 2011; Rawnsley and Spiller, 2012). This condition has resulted in increasingly larger urban settlements. Modern cities have been generally designed as extractive engines drawing resources from natural systems, processing these resources to generate value, and producing wastes whose impacts are externalized. These input output transactions were likened to an organism by Wolman (1965); and this way of thinking has experienced a resurgence in popularity in recent years (e.g, Baccini and Brunner, 2012; e.g. Gandy, 2004; Girardet, 2010; Newman and Kenworthy, 1999). Just as organisms have metabolism, cities have a metabolism – an urban metabolism to maintain their structure, grow and respond to their environment and which can impact heavily on its local, regional and global environment. Not only do different cities have different metabolisms, different *parts* of the city also demonstrate considerable variations in urban metabolism. This paper will seek to quantify urban metabolism in these different city parts. This new understanding of how cities work can show how such cities may shift from being extractive to regenerative so they once again allow human society to live within local, regional and global ecosystem boundaries.

1.2.2. The nature of the problem

To reflect the central role of human activity upon the geology and ecology upon the current phase of earth history, it has been proposed and widely accepted that this geologic epoch be called "the Anthropocene" (Crutzen and Stoermer, 2000; Steffen et al., 2011). Material and substance flow analysis (Baccini and Brunner, 2012;