Cities 70 (2017) 91–110

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Urban metabolism: A review with reference to Cape Town

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ARTICLE INFO

Keywords:
Urban metabolism
Resource flows
Cape Town
Sustainability
Urban planning

ABSTRACT

Improved sustainability of cities requires equitably distributed and ecologically safe, if not restorative, infrastructure systems, as well as reduced reliance on resources from beyond urban boundaries. To shape infrastructure systems in a sustainable and equitable manner, knowledge about the sources and demands of the resources they convey is necessary, as well as the technologies which ensure their efficient use and safe return to the environment. This paper undertakes a basic urban metabolism assessment to examine resource consumption in the City of Cape Town. It examines the type and quantity of resources which fuel the city and its people, in order to highlight prospects for the sustainability of Cape Town. Key findings from resource profiles of Cape Town show that annual energy and water consumption, which are feared to be approaching system limits, have actually shown decline in consumption since 2007 and 2011 respectively. The key intervention to reduce energy consumption and resultant carbon emissions lies in reducing low-occupancy private car usage, while the key limitations to reducing raw water abstraction through wastewater reuse is the limited ability to store and redistribute it. Comparing maps of resource access to maps of material stocks shows that while the city periphery experiences low resource access, resource stocks are potentially quite dense. The spatial location of resource stock, flow and consumption represents a useful tool for detailed urban planning and service delivery, and is a gap in need of researching. Although flows of food are difficult to track, estimates suggest that 11.6% of the food processed in Cape Town is grown within municipal boundaries and interventions for keeping nutrients in the system should be explored. Examining the flow of people between suburbs over time shows that migration dynamics are entrenching poverty in already high poverty suburbs, as people with economic means are more likely to move to better serviced suburbs than invest in their current ones. This presents a need for the city to invest in these underserviced areas, so as to retain personal investment. Key recommendations for urban and resource planning are the integrated analysis of resource nexuses using system dynamics modelling, as well as integrating departments within the municipality, to enable more holistic intervention strategies. To aid this, research into a baseline examination of differential spatial and temporal flows of resources at suburb level is currently underway.

1. Introduction

Urban metabolism refers to "a complexity of socio-technical and socio-ecological processes by which flows of materials, energy, people and information shape the city, service the needs of its populace, and impact the surrounding hinterland" (Currie & Musango, 2016). It is a useful concept for understanding the relationship of resource flows with urban society and its environmental hinterland. Newell and Cousins (2015) identify urban metabolism as a *boundary concept* to bridge the discourses of Marxist ecology (inequality), urban ecology (socio-ecological systems) and industrial ecology (energy and material flows). The concept is also invaluable for addressing sustainability imperatives as related to resource flows, as it is also concerned directly with addressing the *needs of the population*, a focal point of the 1987 WCED definition of Sustainable Development (WCED, 1987). As cities are concentrators of resources and pollutants, global benefits emerge from managing urban infrastructure systems in a sustainable manner.

Whether a city can be truly sustainable is debatable. This is due to varying priorities with which cities contend, the manner in which their boundaries are delineated, and the challenges in identifying and measuring appropriate indicators of urban sustainability. In addition, the vision of a *sustainable city* as a utopian entity is potentially unhelpful as it may impose a contextual or unrealistic development pathways on the city (Campbell, 1996). Swyngedouw and Heynen (2003, 901) and Allen

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http://dx.doi.org/10.1016/j.cities.2017.06.005
Received 9 December 2016; Received in revised form 6 June 2017; Accepted 9 June 2017
0264-2751/

(2014) argue that cities are not either sustainable or unsustainable, but rather encompass various socio-economic and socio-ecological processes "that negatively affect some social groups while benefiting others." Critiquing the tri-part view of social, environmental and economic sustainability as overlooking the inherent trade-offs or contradictions in addressing these simultaneously, Allen (2001) argues that physical and political considerations are necessary for urban sustainability. The first is important as the urban built environment, and the relationships it supports between resources and people (socio-technical systems), enable and shape all urban functions. This is visible through processes of urban agglomeration which bring resources, labour, industry, housing and transportation into proximity (Fernández, 2014). Agglomerative processes result in a tension between benefits of improved employment, healthcare, education or public space, and negative urban attributes such as crime, traffic, disease, crowding, poverty, inequality, ecological degradation and overburdened infrastructure (Turok, 2014). Ensuring equitable and ecologically safe physical infrastructure will address the emergent socio-economic challenges in cities.

In many African contexts, the increased consumption expected from an expanding middle class is in direct tension with resource limits and environmental degradation. This requires that equity of resource access be delivered in resource efficient manners. Consideration of political dimensions of sustainability is important as ignoring political realities, particularly in many African nations, undermines realistic intervention propositions (Godard, 2013). Instead, an approach of *situated urban political ecology* is promoted by Lawhon, Ernstson, and Silver (2014), who call for the need to start from theories and empirics of African urbanism in planning for sustainable urban development.

To improve the sustainability of cities requires addressing natural, economic, social physical and political dimensions of urban sustainability, as well as recognising that they cross geographic and multiscale governance boundaries. Cities are open systems, reliant on their hinterlands for energy, water, food, goods and other flows of resources (Baccini & Brunner, 2012; Rees & Wackernagel, 1996). Urban administrative boundaries, even if they manage to include the entirety of built environment, rarely include the wider biosphere and watershed, and certainly excludes the global trade system, diminishing a city's ability to influence these systems and secure its needs (Bai, 2007). From this bioregional perspective, improving the sustainability of a city not only requires shaping its internal socio-technical dynamics to support social inclusivity and ecological restoration (internal sustainability), but also reducing reliance on resources beyond its boundaries and political purview, through improvements to self-sufficiency[1] (relational sustainability). This pathway may be unrealistic, given the globalised nature of the economy, but cognisance of the wider sense of impact may improve the efficacy of local innovations. To this end, examining urban metabolic functions provides insight into the most effective intervention points for re-shaping internal systems, as well as opportunities for reducing external reliance and global impact.

The difficulties in examining urban metabolism include (i) data scarcity at the city level, particularly in cities of the global South, and particularly in African cities (Currie, Lay-Sleeper, Fernández, Kim, & Musango, 2015), (ii) difficulty in tracking informal, unregulated, illegal or decentralized systems, which in most of the world includes flows of food, material and informal goods, but in the global South also extends to water and energy distribution (Currie et al., 2015; Kovacic, Smit, Musango, Brent, & Giampietro, 2016), (iii) a lack of standardized method for examining urban metabolism, making comparison of cities' metabolisms quite difficult (Beloin-Saint-Pierre et al., 2016; Kennedy, Cuddihy, & Engel-Yan, 2007), (iv) the fluid nature of urban metabolisms, particularly in African urbanism, which are difficult to express in static quantifications, and (v) the nature of cities as open systems, which extends the cities' ecological footprint beyond its point of political or administrative control (Bai, 2007; Hoekman, 2015). Each of these limitations to academic and practical urban metabolism research become less restricting with greater data collection and availability, and there are many calls from urban practitioners for more detailed and wider ranging data at the city level (Economist Intelligence Unit, 2011; Ferrao & Fernández, 2013; Kennedy, Stewart, Ibrahim, Facchini, & Mele, 2014; Kennedy et al., 2007).

Despite its potential as a planning tool, the concept of urban metabolism has not been fully embedded in urban planning processes, which means that much of the examinations of resource flows in cities is ad hoc, and often disconnected from decision makers. In addition, few urban metabolism studies have been completed in the global South, where much of the urban growth is expected. However, more studies have been emerging since 2000 including in Bogota (Pina & Martinez, 2014; Vergara, Damgaard, & Gomez, 2016), Curitiba (Conke & Ferreira, 2015), Mexico City and Santiago de Chile (Guibrunet, Sanzana Calvet, & Castán Broto, 2016), Cairo (Attia & Khalil, 2015), Cape Town (Gasson, 2002; Hoekman & von Blottnitz, 2016; Swilling & Davison, 2010), and many cities in China (e.g. Guo, Hu, Zhang, Huang, & Xiao, 2014; Liang & Zhang, 2012; Lu et al., 2016; Zhang, Yang, & Fath, 2010; Zhang, Yang, & Xiangyi, 2009).

Ferrao and Fernández (2013) present a conceptual framework by which a city can make best use of a variety of urban metabolism assessment tools. They propose a multilayered examination of (i) urban bulk mass balance, (ii) urban material flow analysis, (iii) product dynamics, or life cycle assessment, (iv) material intensity by economic sector, (iv) environmental pressure of material consumption, (vi) spatial location of resource use, and (vii) transportation dynamics (Ferrao & Fernández, 2013). These range from simple analyses of typically available data, to more time and resource intense forms of analysis. With each of these layers, urban decision makers get specific indicators of how their cities are functioning which are directly relevant to sustainability interventions. To support a multilayered investigation, a baseline of existing data and policy is necessary. Musango et al. (in press) extend Kennedy et al.'s (2014) indicator set and promote undertaking *basic urban metabolism assessments*, which capture indicators of urban context, biophysical parameters, energy metabolism parameters and the role of utilities[2] as well as policy frameworks around urban planning, infrastructure and resource consumption.

This paper reviews the state of knowledge of resource flows and wider metabolic functions in the city of Cape Town, South Africa (henceforth referred to as *Cape Town*). It is the first in a series of investigations undertaken by the authors to provide basic urban metabolism assessments of African cities. Cape Town is unique to the African context as much research has already been produced around the issue of resource flows, resource access and urban sustainability from a resource equity perspective as much as from an efficiency perspective (e.g. Battersby, 2011; Gasson, 2002; Hoekman & von Blottnitz, 2016; Hyman, 2013; Jaglin, 2014; Smith, 2001; Swilling, 2010). A large amount of socioeconomic and resource consumption data is thus available for Cape Town. In fact, four of Ferrao and Fernández's (2013) layers have been fully or partially estimated for Cape Town, namely (i) urban bulk mass balance (Currie, 2015; Saldivar-Sali, 2010), (ii) urban

[1] Sustainability tends to be measured as a comparative state, in which an entity is more or less sustainable (along any of Allen's (2001) five dimensions) than another. This manner of assessing sustainability effectively excludes the more complex discussions of *sufficiency* as well as which form of urban living may allow the most acceptable, sufficient or best quality of life. These questions require an examination of the values which underscore human relationships with each other, and with the natural and built environments. Such explorations exist (e.g. Rees & Wackernagel, 1996; Newman, 1999; Devall, 2001; Fioramonti, 2017), but have not necessarily become the mainstream practice, and as such, sustainability remains a comparative measure. This paper does not attempt to answer the question of how best to measure urban sustainability, but identifies it an important need.

[2] These indicator sets are promoted in Kennedy et al. (2014) with policy frameworks argued for in Musango et al. (in press).