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Developing a multi-layered indicator set for urban metabolism studies in megacities

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ABSTRACT

We introduce a new 'multi-layered' indicator set for urban metabolism (UM) studies in megacities. The indicator set is designed for gathering information on the definition (spatial boundaries, constituent cities, population, economy), biophysical characteristics (climate, population density, building floor area), and metabolic flows (water, waste, materials, and all types of energy) of megacities. In addition, it addresses the role of utilities in the provision of services and regulatory actions that, along with public governance, may influence (and/or control) the urban metabolism. In the article, we give background context to the growth and development of megacities, their overarching socio-economic issues, and the definition of their boundaries. Two methodologies to define megacity boundaries are compared, showing that the definition of 'megacity' is not trivial and that further investigation is needed to establish a baseline for comparison of urban metabolism data. Use of the standardized indicator set will ease inter-city comparisons of urban metabolism, whilst enhancing knowledge of megacities and their transformation into sustainable systems.

1. Introduction

> As the 21st century dawns, megacities – great and far-reaching concentrations of power and influence – have become centers of the phenomena of globalization and information exchange. These concentrations of people and activity are placing stress on the natural environment so great that it is beginning to have extensive regional, and even global impacts.
>
> Liddle and Moavenzadeh (2002)

The 21st century is the century of the city: by 2050, the world's urban population is expected to reach 6.5 billion, up from 3.5 billion in 2010. At the upper end of global urbanization has been the increasing emergence of megacities, i.e., metropolitan regions with over 10 million people. In 1970, there were only eight megacities: Tokyo, Osaka, Seoul, Moscow, New York, Los Angeles, Mexico City, and São Paulo (Fig. 1). By 1980, that number had increased to 9, and by 2010 it reached 27 (Fig. 2 and Table 1). This remarkable growth period is exemplified by cities like Guangzhou (China) and Delhi (India), each with populations of less than 5 million in 1970, but today with populations exceeding 15 million. By 2020, there will be an estimated 39 megacities in the world for a combined total of 685 million people. Compared to 2010, this marks a 50% increase in the total population of all megacities.

Although megacities are a global phenomenon, the majority of current (and future) megacities are located in low to middle income countries. Most megacities in high-income countries are growing slowly, if at all, while those in lower-income regions (particularly Africa and South Asia) are growing rapidly, placing enormous pressure on infrastructure and resource consumption (Siemens, 2007; Angel et al., 2012). In the past 40 years, cities in these regions have added nearly 2.5 billion people to the total global population (Angel et al., 2012). The developmental challenges that these megacities face in a time of resource constraint and climate change are immense.

Despite the critical need for studies of resource consumption in megacities, the multi-jurisdictional governance structures of these urban mega-systems have thwarted comparative study. The resource flows into megacities, and the wastes produced, likely have environmental implications on a planetary scale. Unlike in nations, however, the quantification of resource and waste flows in these giant cities is rarely undertaken. Lack of such data may significantly hamper policy development; research that seeks to understand the sustainable development of megacities is therefore imperative.

We have designed a new indicator set to facilitate the collection of standardized urban metabolism (UM) data from megacities. The

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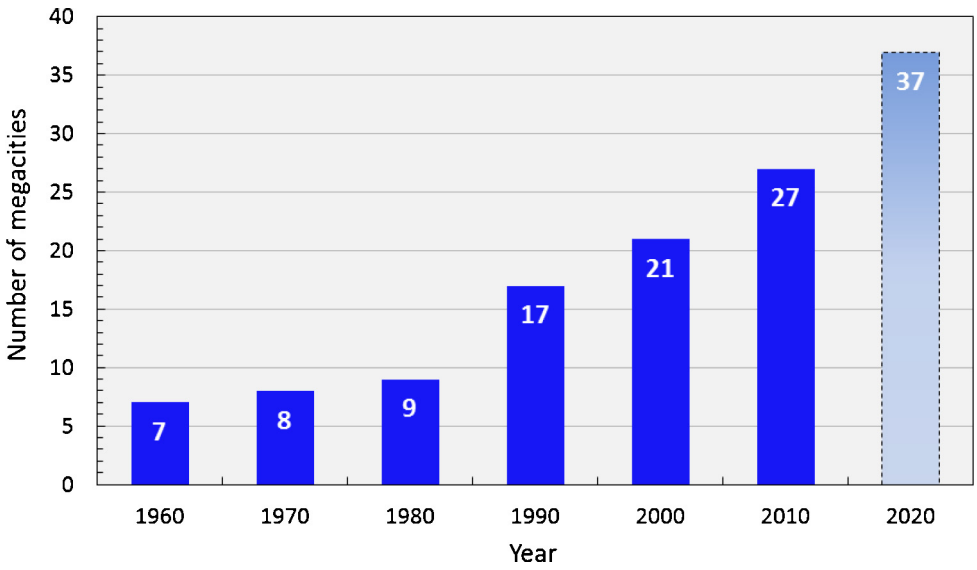

Fig. 1. The number of megacities at the start of each decade since 1960, with authors' projection to 2020.

specific aim of the indicator set is to identify general biophysical and socio-economic characteristics (e.g., population density, heating degree days, GDP) that are independent of the specific urban system, and that can be used to compare megacities and their resource flows. These data can underpin further inquiry into urban metabolism in megacities, to include measure of quality of life, the role of utilities, and the potential for integrated infrastructure solutions, electric mobility, and improved resource efficiency.

In this article, we discuss our approach to designing the new indicator set, and emphasize its importance to studies of megacities and resource flows. We give an operational definition of 'urban metabolism' and justify the need to conduct UM studies in megacities. Several related issues are discussed, such as the growth processes in megacities, the difficulty to define spatial boundaries of megacities, and the role of utilities in sustainable megacity development. Each of these discussions is linked to the content and specific aims of the UM indicator set. We close the article by recognizing the enormous development challenges that megacities face in low and middle income countries.

2. The metabolism of cities

Urban metabolism is defined as "the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" (Kennedy et al., 2007). Urban metabolism is therefore a scientific phenomenon comprising individual processes that occur in all cities at different spatial and temporal scales. The study of these processes, or the energy and material flows of cities, is a relatively new field. The first formal metabolism study was conducted by Wolman

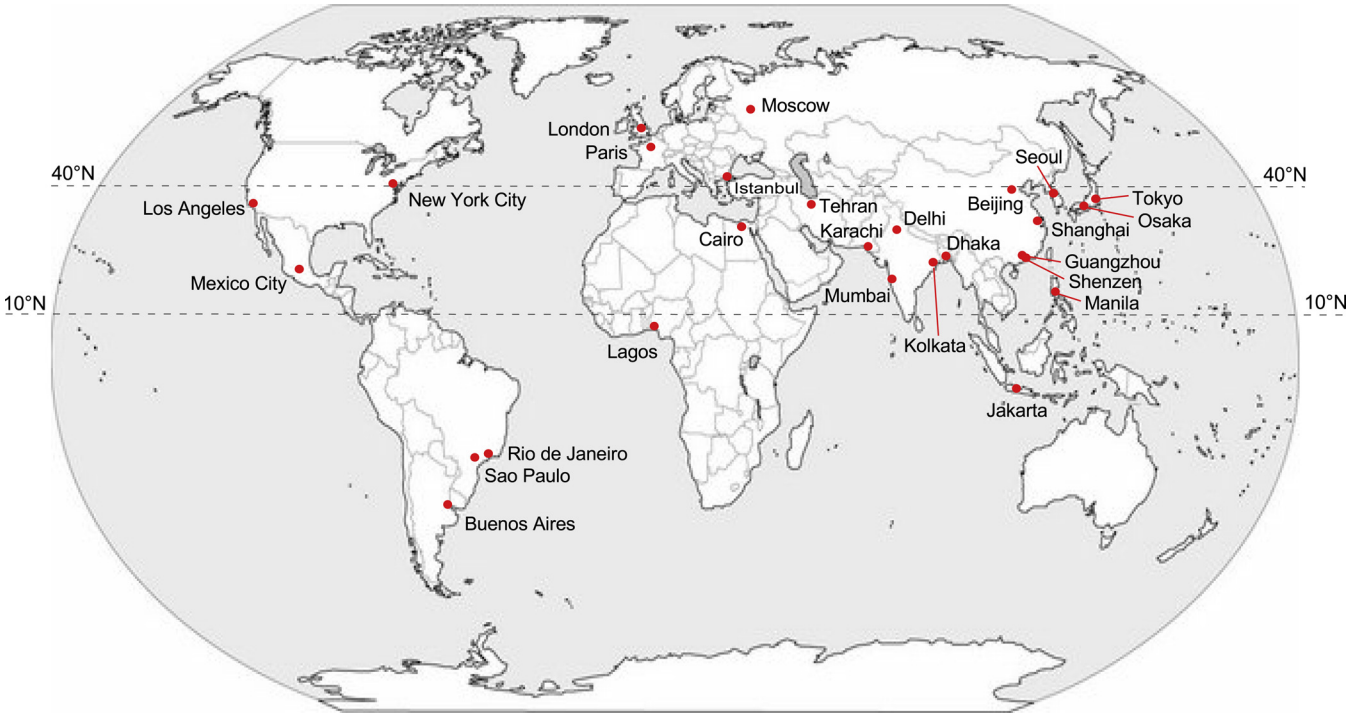

Fig. 2. The world's 27 megacities and the '10/40' window.