POPULAR SCIENTIFIC ABSTRACT

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[Revealing Patterns of Urban Built Environment Stocks Across and Within Cities: A Chinese Case Study]

Urban built environment stocks, especially buildings and transportation infrastructures, provide basic services to humans and set the physical boundary for cities. China, as the largest developing country, is experiencing unprecedented urbanization associated with intensive construction of buildings and infrastructures, which resulted in growing natural resource and energy demands. Improving our understanding of the composition, weight, spatial distribution and growth patterns of built environment stocks in China could thus help inform urban resource, waste, and environmental management for sustainable development. However, this is often hampered by knowledge and data gaps such as inaccessible physical size, inconsistency typology, undefined age, and inaccuracy material composition data of buildings and infrastructures.

This thesis aims at revealing the development patterns of urban built environment stocks across and within cities, using Chinese cities as a case study. Bottom-up material stocks accounting method, Geographical Information System (GIS) tools, big data mining and analytics techniques, and local material composition database are integrated to address the abovementioned knowledge and data gaps in stock characterization. Specifically, the physical size of buildings and transportation infrastructures were obtained from statistics (e.g., annual subway length) and GIS database (e.g., building footprint including location, geometry and height). Big data mining techniques were applied to derive the attributes (i.e., typology and age) for individual buildings. The localized Chinese specific material composition indicators were compiled from over 2,000 building samples and hundreds of construction processes in infrastructure inventories. GIS-based bottom-up stock accounting method was then applied to estimate the material quantity and composition of urban built environment stocks in three case studies: China's subway networks, an example for Beijing, and an estimation for the 50 Chinese cities. Patterns analyses and environmental impact analyses were further conducted to reveal the spatial and temporal patterns and the embodied greenhouse gas emissions of urban built environment stocks for sustainable implications.

Firstly, the pathways of Chinese urban subway development, materials accumulation, and embodied greenhouse gas emissions from 1971 to 2020 were analyzed. Results illustrated a moderate and steady growth before 2010 and a rapid expansion afterwards, provoked by the infrastructure upgrading investment after the 2008 global financial crisis. In total, 6,004 km of subway networks (that is, 37% of the global total length), 1 gigaton of material stocks, and 261 megatons of embodied greenhouse gas emissions are accumulated in China's subway in 2020. This booming subway construction implies the late-development advantages and infrastructure-based urbanization mode in China.

Secondly, Beijing's urban built environment stocks were characterized at a high spatial distribution (in 500 m × 500 m grids). This case study found that totally 3,621 megatons (or 140 t/cap) of construction materials were stocked in buildings and infrastructure in 2018 in Beijing, equaling to 1,141 megatons of embodied greenhouse gas emissions. Material stocks analysis combined with emerging big data techniques in this case study help realize more spatially refined characterization of built environment stocks and highlight the role of such information and spatial planning for urban resource, waste and environmental strategies.

Finally, bottom-up accounting method was applied to estimate the quantity and composition of the infrastructure material stocks in 50 Chinses cities, and the building material stocks in Beijing, Guangzhou and Shenzhen. The estimated building material stocks were further used to predict the stocks in the remaining 47 cities with unknown building typologies by the integration of building footprint data (e.g., geometries, floor area, and height) and point of interest data in a random forest algorithm. In total, the urban built-environment stocks of the 50 Chinese cities reached 101 gigatons in 2020 (227 t/cap and 4.5 t/m2), dominated by building (in terms of end-use category, 70.8 gigatons) and gravel (in terms of material composition, 42.9 gigatons), and the embodied greenhouse gas emissions amounted to 31 gigatons. The linear distribution of infrastructure stocks and the diverse spatial patterns of building material stocks were revealed across cities. Urban building material stocks in 500 m × 500 m grids were spatially showing a development trend of "concentration - dispersion - concentration", with a GINI index varying from 0.57 to 0.68 and 0.60 in the three material accumulation stages.

Our results on the urban built environment stock for China, as the largest country with the most population and the second greatest economy, could shed light on addressing urban sustainability in other countries and globally as well.