THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

RESEARCH CENTRE FOR RESOURCES ENGINEERING TOWARDS CARBON NEUTRALITY
±RCRE 碳中和資源工程研究中心

Quantifying Potential Anthropogenic Resources of Buildings through Hot Spot Analysis

Dr. Mark Shu-Chien Hsu, The Hong Kong Polytechnic University
Prof. Hwong-Wen Ma, National Taiwan University

Background

- Urban mining is one of many practical strategies for transforming a society into a circular economy (CE) (Brunner, 2007; Cossu, 2013; Cossu and Williams, 2015; Pauliuk et al., 2012; Simoni et al., 2015). As natural resources are depleting, the traditional linear economy (take-make-dispose) is no longer practical. Converting to a CE would be a solution towards sustainable development (Frosch and Gallopoulos, 1989).
- Over the past two centuries, driven by industrialization and urbanization, enormous amounts of raw material have been extracted from nature to become a part of the anthroposphere and aggregated into urban ores. These ores are regarded as material stocks (MS) in socioeconomic metabolism (SEM), and exploiting these MS through various technologies is called urban mining (Cossu and Williams, 2015; Graedel, 2011; Halada et al., 2009; Jacobs, 1961; Johansson et al., 2013; Kennedy et al., 2007; Lederer et al., 2016).
- Numerous SEM studies have investigated material flows at the macro level, but there are few studies that focus on material stocks at the micro scale (Fishman et al., 2014; Lederer et al., 2014; Tanikawa et al., 2015). Since this MS is of great potential to be developed into useful resources, they have to be accurately quantified and carefully managed.
- Resources are consumed, and pollutants are generated during the construction, operation, and disposal of these buildings (Kennedy et al., 2007). During the construction stage, massive construction materials are needed, often consisting of a huge amount of minerals such as gravel, limestone, clay, iron ore, coal, silica ore, and bauxite. This leads to the depletion of natural resources, which causes severe environmental problems.
- Basic information about urban ores includes quantity, composition, spatial attribute, and age (Brunner, 2011; Graedel, 2011; Tanikawa et al., 2015; Tanikawa and Hashimoto, 2009). Most of the previous MS studies have usually conducted top-down material flow analysis (MFA) on a macro scale. This research has received criticism for its failure to provide more than basic urban ore information, and for treating the economy as a black box, only considering a net addition to stocks (NAS) as a balancing factor for inflows and outflows (Augiseau and Barles, 2017; Tanikawa et al., 2015).
- Though bottom-up MFA could obtain information on a smaller scale, it only evaluates the NAS without knowing the quantity of the accumulated stocks in a particular area, and the time and labor costs involved in performing MFA are high (Ciacci et al., 2017; Kral et al., 2014; Wang et al., 2016).

Objective and Scope

This study aims to accurately capture urban ore's basic information and assess potential locations for extraction. Detailed building statistical data includes the date of construction, building structure, use of buildings, TGFA, number of floors, building address, etc. GIS data were acquired from the Taipei government to analyze the potential construction material stocks in Taipei for the past 50 years.

Data and methodology

In a micro-urban system, this study uses the total gross floor area (m^2) and the material intensity (kg/m^2) of the buildings in the district to quantify the total material stock (kg). The bottom-up MSA (Kleemann et al., 2017; Tanikawa et al., 2015; Tanikawa and Hashimoto, 2009) is expressed by equation (1). After the MS is quantified, this study combines the GIS data to get a high-resolution MS spatial distribution of the city. The steps of localization are explained as follows.

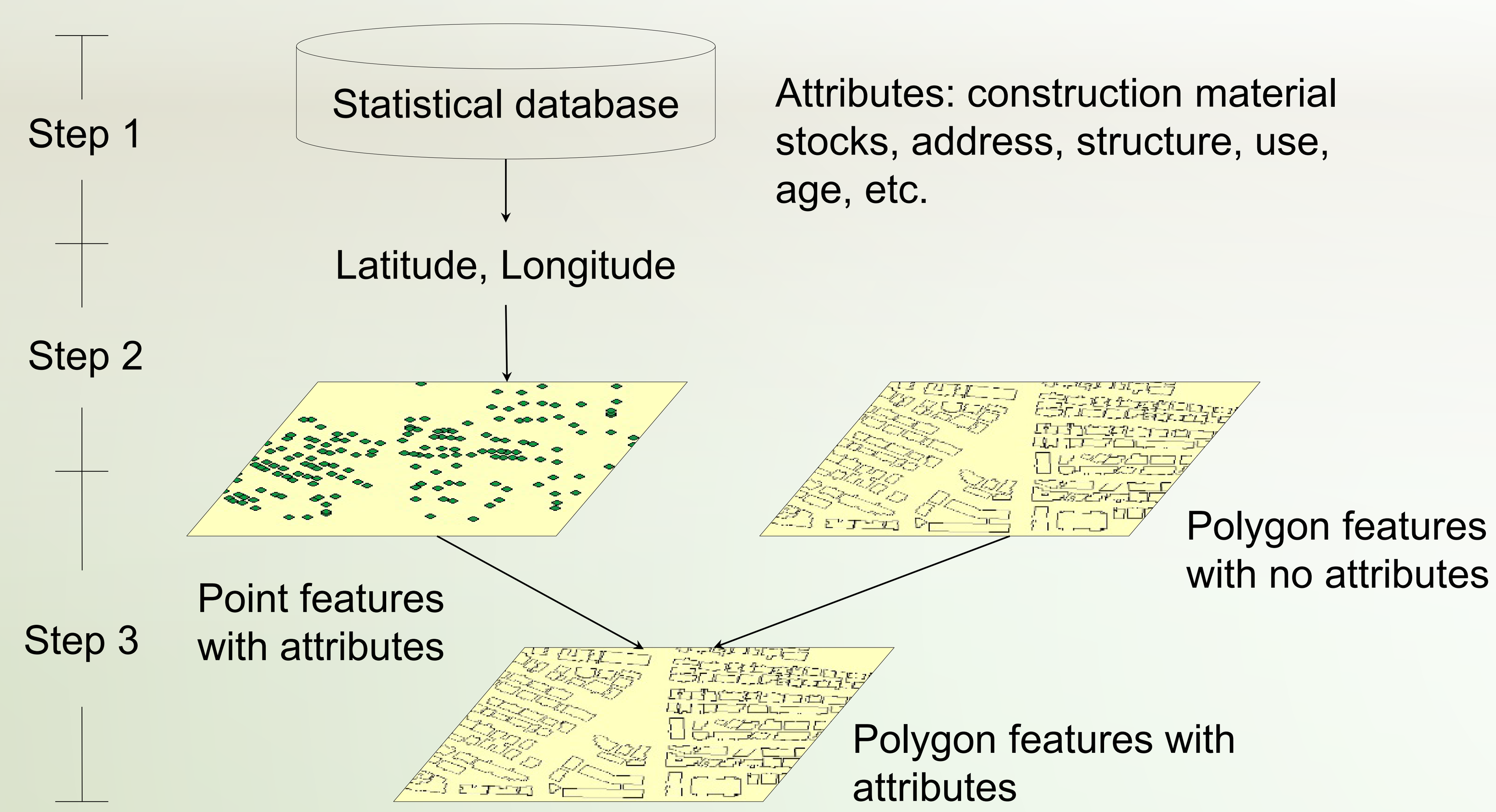
$$MS = \sum_{m,i,j,t}^{k,l,n,o} \left(TGFA_{i,j,t} \times MI_{m,i,j}\right) \quad (1)$$

MS = the total material stock (kg)

$TGFA_{i,j,t}$ = the total gross floor area of the building of structure i with building use j in year t (m^2)

$MI_{m,i,j}$ = the content of material m per total floor areas of the buildings of structure i with building use j (kg/m^2)

Localization of Material Stocks



Hot spot analysis

After the MS is localized, the Getis-Ord's Gi*(d) statistic of hot spot analysis (HSA) is applied to locate the old building clusters with high extraction potential. The indicator Gi*(d) is defined as follows (Getis and Ord, 1992):

$$G_i^*(d) = \frac{\sum_{j=1}^{n} w_{ij}(d) x_j}{\sum_{j=1}^{n} x_j} \quad (2)$$

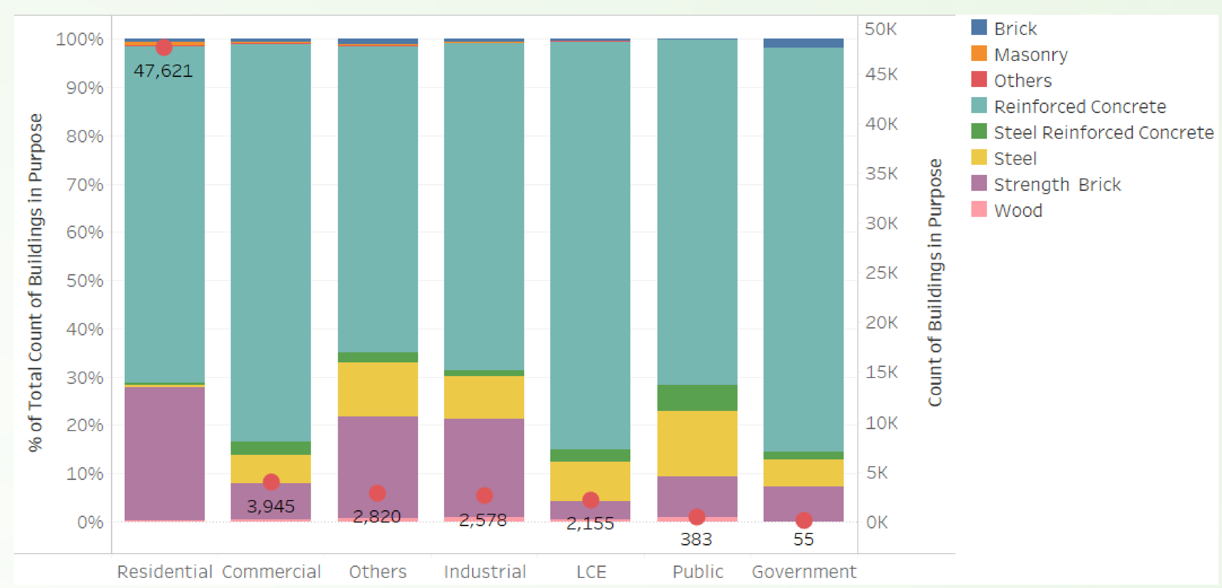
with x_i and x_j = attributive values of the inspected variable in spatial units i and j (years)

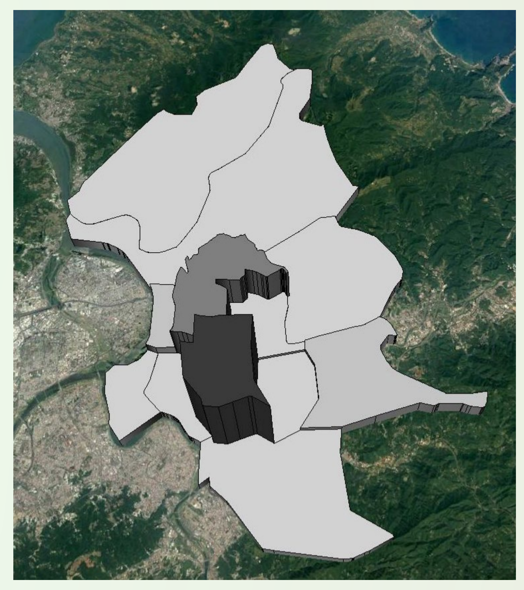
d = distance (m)

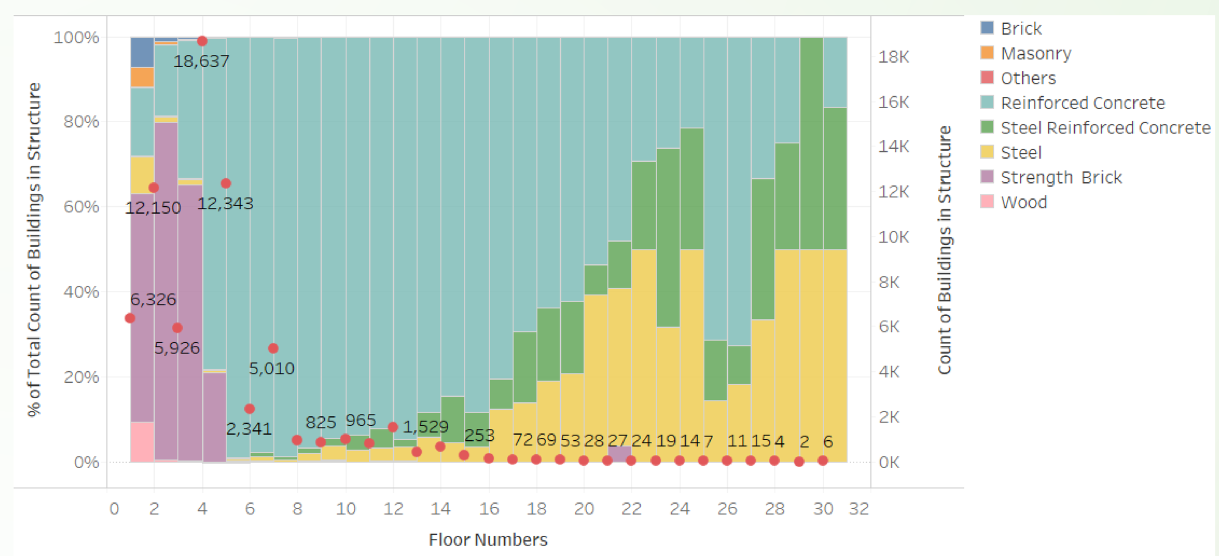
$w_{ij}(d)$ = weighted matrix

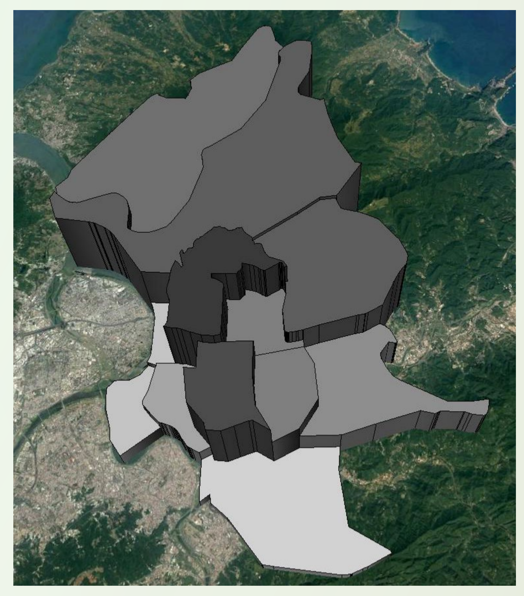
Case study

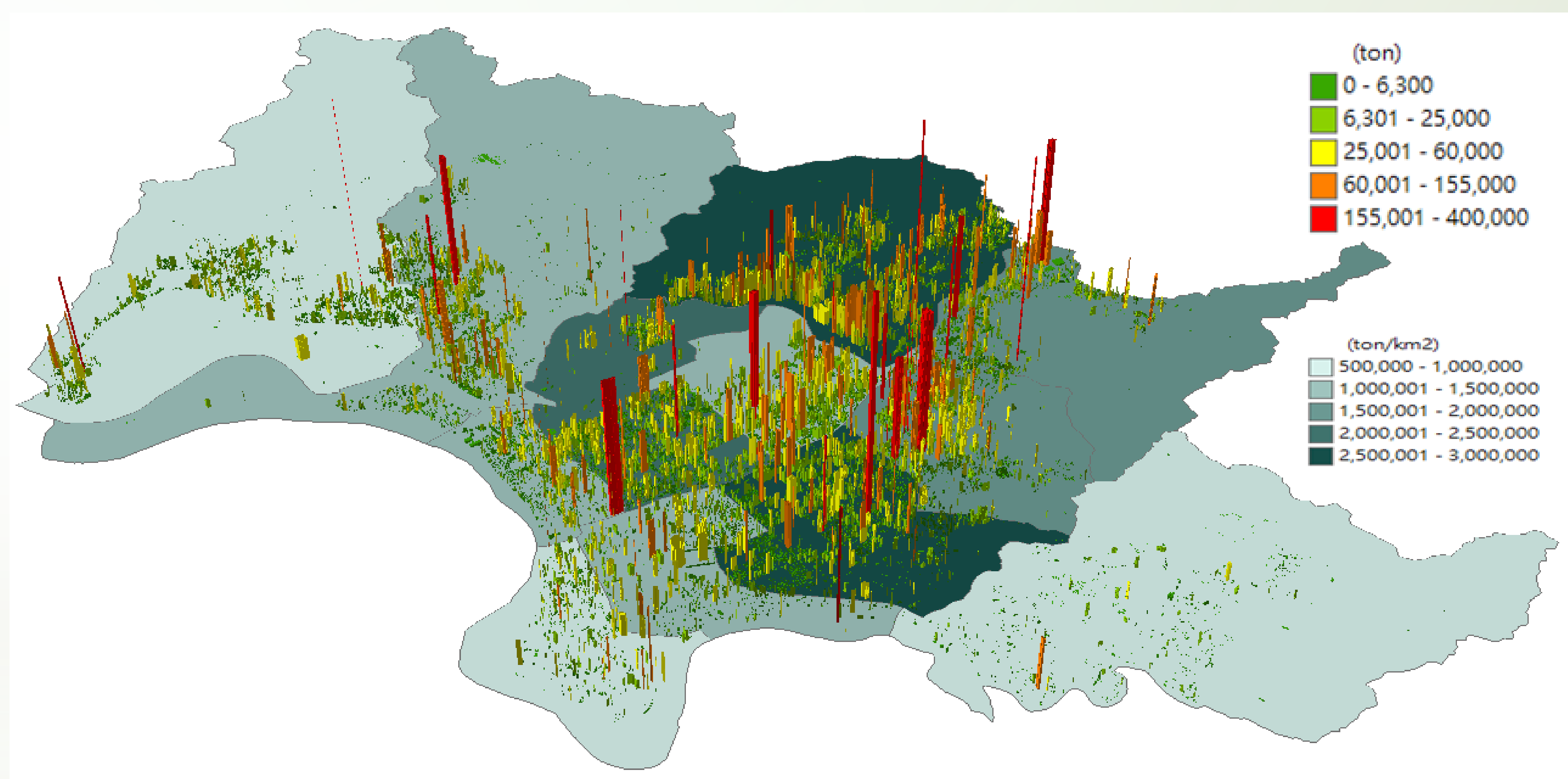
The urban ores stocked in the city today are the resources of tomorrow (Brunner, 2007). These ores are significant to the resource-depleted world, especially for Taiwan. Taiwan is an island that lacks natural resources and is highly dependent on imports to meet its demand.











Spatial distribution of the material stock in buildings in Taipei City.

Summary and Findings

- This study focuses on the preliminary stage to the medium-term of the urban mining process, including the quantification and spatialization of urban ores, but without considering the feasibility of exploitation.
- The analysis on the relationship of the building structure, number of floors, and age in this study could serve as a reference for areas lacking information related to the building structure
- MS could be combined with the material flow to build a dynamic material flow model for assessing the quantity of extractable urban ores, and the feasibility of exploitation in the future.

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