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Towards a more circular construction sector: Estimating and spatialising current and future non-structural material replacement flows to maintain urban building stocks

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ABSTRACT

Humans are extracting and consuming unprecedented quantities of materials from the earth's crust. The construction sector and the built environment are major drivers of this consumption which is concentrated in cities.

This paper proposes a framework to quantify, spatialise and estimate future material replacement flows to maintain urban building stocks. It uses a dynamic, stock-driven, and bottom-up model applied to the City of Melbourne, Australia to evaluate the status of its current material stock as well as estimated replacements of non-structural materials from 2018 to 2030. The model offers a high level of detail and characterises individual materials within construction assemblies for each of the 13 075 buildings modelled.

Results show that plasterboard (7 175 t), carpet (7 116 t), timber (6 097 t) and ceramics (3 500 t) have the highest average annual replacement rate over the studied time period. Overall, replacing non-structural materials resulted in a significant flow of 26 kt/annum, 36 kg/(capita·annum) or 721 t/(km^2·annum). These figures were found to be compatible with official waste statistics. Results include maps depicting which material quantities are estimated to be replaced in each building, as well as an age pyramid of materials, representing the accumulation of materials in the stock, according to their service lives. The proposed model can inform decision-making for a more circular construction sector.

1. Introduction

Over the last century, the global population and material consumption increased by a factor of ~4 and ~10, respectively (Krausmann et al., 2009). According to the same study, the use of construction minerals increased by a factor of 42. This dramatic increase in annual material consumption per capita has resulted in the accumulation of 792 Gt of materials within in-use stocks of buildings, buildings, infrastructure and other manufactured goods in 2010. This represents a stock accumulation 23 times higher than at the start of the twentieth century (Krausmann et al., 2017). Krausmann et al. (2017) also indicate that growth in material use and accumulation is unevenly distributed across the world, with stock growth in China accelerating exponentially over the last decades. For instance, cement production in China alone accounted for 55% of global production for the year 2010. From 2011 to 2013, China produced as much cement as the United States did, over the twentieth century (Smil, 2013).

The unprecedented material consumption experienced after 1945 can be associated with the creation and expansion of cities across the world as well as the rapid increase of global urban population. The latter is projected to further increase by ~3 billion people by 2050 (United Nations-Department of Economic and Social Affairs (UN), 2014), most of which in developing economies. This is expected to lead to the creation of new urban areas, and associated additional material consumption.

When aligning these figures, the material requirements of modern societies, spearheaded by cities and urban centres, become a self-evident societal, environmental and economic concern (Matthews et al., 2000). In fact, current volumes and trends of global material consumption and energy use drive local and global environmental impacts, including resource depletion, climate change, and waste, among others (Prior et al., 2012; Seto et al., 2014). In addition, the current linear economic model further intensifies anthropogenic stress on natural resources, namely because of a very high demand for raw material extraction on one side, and a significant dumping of pollutants and discarded materials on the other, beyond the assimilative capacity of ecosystems.

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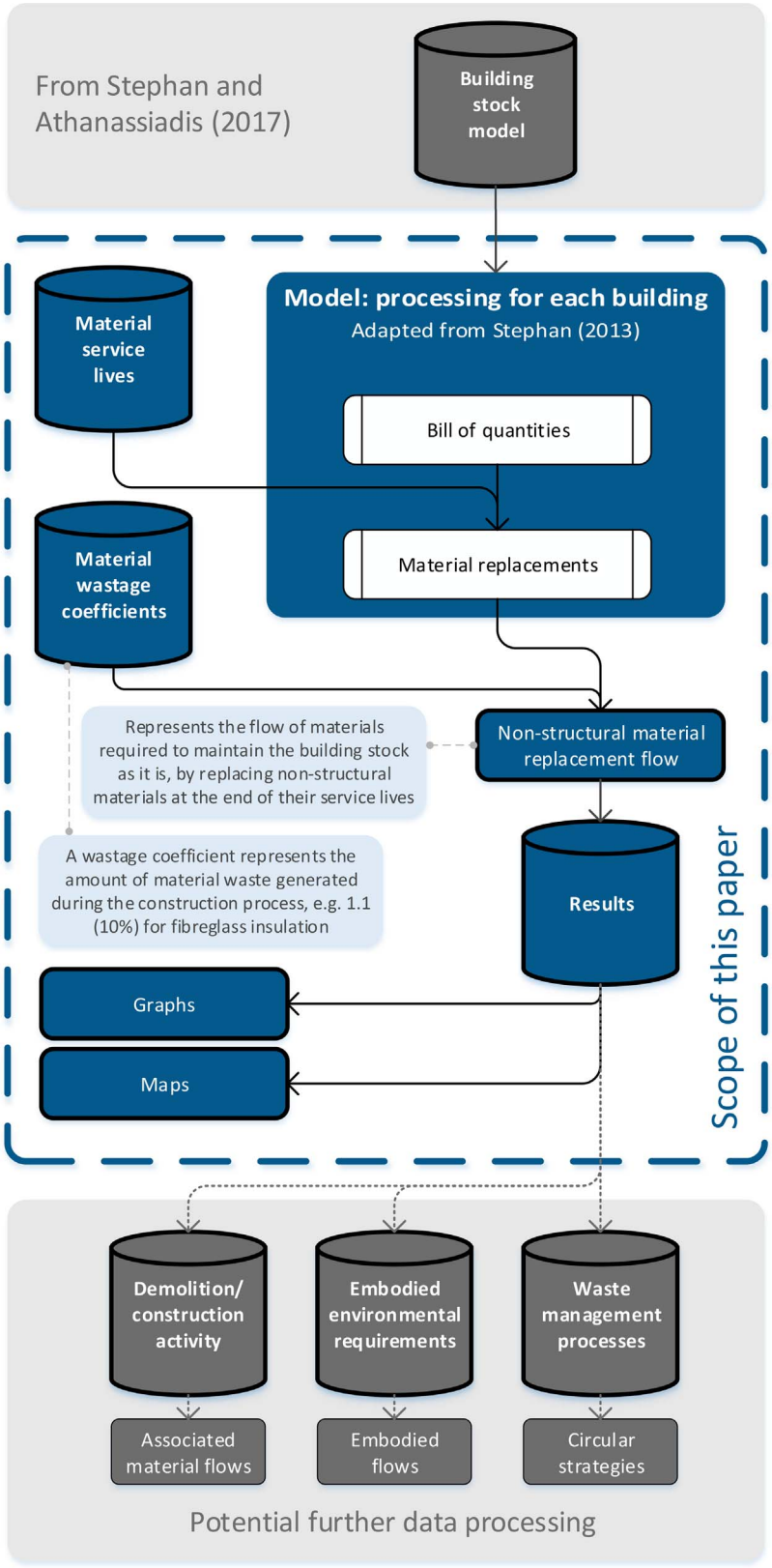

Fig. 1. Overall modelling approach and scope.

The construction sector and the built environment consume the largest share of materials, globally (Schandl et al., 2016), and represent the highest share of local waste production (Athanassiadis et al., 2016). The significance of the construction sector in terms of material consumption is expected to further increase in the future (Fishman et al., 2016).The transition towards a more circular economy where output flows could be reintegrated as secondary resources is being presented as a promising solution at the construction sector (ABN-AMRO and Circle Economy, 2014; World Economic Forum, 2016), city (City of Amsterdam, 2014; Institut d'Aménagement et d'Urbanisme de l'Ile-de-France, 2013; London Waste and Recycling Board, 2015), national (Geng et al., 2012) and global level (Ellen MacArthur Foundation,