Resources, Conservation & Recycling 138 (2018) 32–39

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

Full length article

Urban mining and buildings: A review of possibilities and limitations

Alexander Koutamanis[a,*], Boukje van Reijn[b], Ellen van Bueren[c]

[a] Delft University of Technology, Faculty of Architecture & the Built Environment, Julianalaan 134, NL-2628 BL, Delft, The Netherlands
[b] NEN – Netherlands Standardization Institute, The Netherlands
[c] Delft University of Technology, Faculty of Architecture & the Built Environment, The Netherlands

ARTICLE INFO

Keywords:
Urban mining
Buildings
Construction and demolition waste
Renovation
BIM (Building Information Modelling)

ABSTRACT

In recent years there has been growing interest in urban mining in buildings from various environmental and economic perspectives. Materials hidden in buildings are attractive alternatives to raw ones and building activities are responsible for a large share of urban waste in many societies. The paper presents an analysis of possibilities for urban mining in Amsterdam, initially focused on metals in residential buildings. Both global literature and local analysis suggest that performance in resource recovery from buildings is already as high as it can get. However, estimation of material content in buildings and of waste processing rates is far from reliable, accurate and precise enough to support such claims or identify possibilities for further improvement, including localization of resources in buildings and connections to building activities, in particular renovation.

1. Introduction

The paper presents the findings of a study on the feasibility of urban mining (UM), initially focused on metals in residential buildings in the city of Amsterdam. It addresses the availability of valuable resources in the built environment as well as the possibilities for their recovery, including the current performance in construction and demolition waste (C&DW) processing. The focus on metals was motivated by current high prices and demand, which make metals attractive targets for all parties involved in C&DW. UM for metals could therefore be considered as an opportune starting point for explorations of potential, as well as for UM deployment in general.

Residential buildings may have smaller sizes, distributed ownership, smaller volume per unit, longer life than industrial or office buildings and a greater variety of materials (Schebek et al., 2017) but in terms of overall building stock, housing is the vast majority: in February 2018 there were 7.746.202 residential properties versus 1.128.965 non-residential ones in the Netherlands (CBS, 2018). Moreover, the way Dutch housing is organized and the high repetition and standardization that characterizes it, are particularly relevant for UM, as they promise structural, regular opportunities.

The findings are considered from the viewpoint of AECO (architecture, engineering, construction and operation of buildings): the disciplines involved in the production and management of the built environment, which could therefore contribute actively to UM. With the recent societal emphasis on circularity, UM connects to the processes of AECO and the information produced and managed by AECO, in particular in the operation stage (up to and including demolition), i.e. with respect to the existing building stock.

The study comprised three main parts:

1 Exploratory literature review of the global state of the art with respect to the estimation of metal content in residential buildings, possibilities for their recovery and measures of current performance in C&DW processing. Particular attention was given to papers that included actual cases as sources of quantitative information, so as to establish a reliable picture of what is available and how it is currently processed.
2 Analysis of local practices, experiences and performance, based on official statistics and semi-structured interviews with Dutch experts in building demolition and waste management. The comparison of local conditions to the literature review aimed at identifying local factors that could stimulate or may limit UM.
3 Evaluation of the utility and applicability of literature review results to the particular context of Amsterdam and the Netherlands:
   a Estimation of resources available in existing building stock
   b Identification of opportunities for the recovery of these resources
   c What is already happening in C&DW processing; possible room for improvement or additional UM activities

* Corresponding author.
E-mail address: a.koutamanis@tudelft.nl (A. Koutamanis).

https://doi.org/10.1016/j.resconrec.2018.06.024
Received 2 April 2018; Received in revised form 26 June 2018; Accepted 26 June 2018

1.1. Urban mining

In recent years, increased demand for many materials and concerns for the effects of waste have stimulated interest in UM from various perspectives, environmental and economic. As concentrations of elements in anthropogenic stocks are often comparable or even higher than natural stocks (Cossu and Williams, 2015), recovering resources from the anthroposphere is an attractive alternative to depleting natural ones, incurring high costs for extraction and transport from primary sources or becoming dependent on those who control the primary sources. The promise seems substantial and widely accepted, concerning not only household waste and end-of-life products like vehicles or electrical and equipment waste (WEEE) but also the built environment, since construction is both a major user of materials and a primary producer of waste (Agamuthu, 2008; Li, 2015).

Although UM originally focused on WEEE, it is increasingly seen as cumulatively and rather indiscriminately applicable to all kinds of waste, produced from various aspects of urban life, despite marked differences between these aspects and resulting kinds of waste or waste processing. Such differences can be critical for UM, e.g. with respect to the lifespan of products and their vitality for human activities while in use. Additionally, UM often focuses on what happens after extraction from the anthroposphere. Availability and improvement of collection rates are also considered but practical and technical issues in pre-processing and physical separation from the environment less so (Tesfaye et al., 2017). In short, UM seems to depart less from resource efficiency (Xue et al., 2017) and more from waste processing of typical urban waste kinds, often as a strategic component of circularity or sustainability (Arora et al., 2017; Cheng et al., 2018).

1.2. Buildings as mines

Buildings have an uneasy fit in the UM framework. This is a reflection of the distinction between two main kinds of resources in UM, stock and flow resources (Cossu and Williams, 2015), the apparent orientation of UM towards the latter and of particular characteristics of building stocks. The lifespan of building components is not only significantly longer to that of e.g. electronic equipment but also quite varied, depending on material, subsystem (e.g. heating, plumbing, electrical or loadbearing), use intensity and weathering. Some analyses suggest that as little as 3% of materials may be extractable from buildings and then only after a protracted lifespan – buildings actually extend the in-use life of many materials (Ciacci et al., 2017; Lederer et al., 2016). This relates to a number of factors particular to buildings, including:

- Buildings are critical and dominant parts of our habitat. We need the protection and comfort they offer and are reluctant to reduce them: the price of scrap steel has to become too high to make one consider relinquishing the central heating pipes and radiators of their homes or offices without a heating alternative.
- The importance of buildings goes beyond practical needs and extends to cultural aspects of society, as evidenced by the large number of listed buildings in many countries.
- Buildings tend to become vintage rather than old, in the sense that they lose little if any value over time. On the contrary, the preeminence of factors like location and the overall similarity in performance between new and older buildings make the value of old buildings often rise together with the price of new ones (Clapp and Salavei, 2010; Coulson and McMillen, 2008; Syed and De Haan, 2017). This too stimulates preservation and maintenance of buildings beyond their assumed functional or technical lifespan.
- As buildings are maintained for quite long periods, they are frequently adapted: their original structure and composition may change substantially and include new materials or subsystems following changes in architectural approach, technology or user requirements, like having central heating in medieval buildings (Grussing, 2014; Méquignon and Ait Haddou, 2014; Struhala and Stranska, 2016). It is often hard to know which resources one might find in a building without extensive research – unlike e.g. household appliances, which may change little even after many repairs.
- Ownership, operational and economic management of buildings is widely distributed and largely uncoordinated, in contrast to other stocks in the built environment like roads and utilities (infrastructure).

In conclusion, buildings may superficially seem to comprise composite waste, in a manner typical of urban mines, but this is merely a picture that emerges from old-fashioned, indiscriminate demolition practices. It is a view that reduces the built environment to rubble prior to considering it as a subject for UM and restricts UM to what takes place after collection, similarly to e.g. WEEE (Arora et al., 2017; Coelho and de Brito, 2013b). It neither acknowledges the habitation function of buildings nor takes into account the structured manner by which materials are organized into building components and elements. This structure determines extraction ease and collection availability, since it is building components that usually turn from in-use to end-of-life products, generally in relation to changes in primary functions, e.g. transition to a different heating system.

1.3. Cities as mines

Recovering resources from the anthroposphere in a densely populated city is a complex task, nevertheless justified by the joint imperative of reducing unprocessed waste and extracting value from existing stocks and flows. Moreover, cities seem to be the right place for it: the larger the size of a community, the higher the building and demolition activity (Huuhka and Lahdensivu, 2016). Waste generation rates (WGR) for C&DW are also higher in countries with higher population densities (Bertram et al., 2002). The underlying reasons include higher economic activity, population mobility, higher living standards and stricter environmental regulations – all characteristic of old yet still dynamic urban centres like Amsterdam. This has not escaped the attention of local authorities: in common with other Dutch cities, Amsterdam has embraced the circular economy concept, developed white papers stating ambitions linked to national policies and established platforms where public and private forerunners as well as knowledge institutes meet to promote circularity (Gemeente_Amsterdam, 2014).

2. Literature review

2.1. Construction and demolition waste

Construction and demolition (C&D) are widely acknowledged as one of the most important sources of waste. C&DW in the Netherlands in 2010 (a lean year for the building industry) amounted to 24 Mt, while industry produced 15 Mt and consumers 9 Mt (Rijkswaterstaat_Leefomgeving, 2013). C&DW is generally divided by its cause: new construction, renovation and demolition. Demolition contributes up to 70% of C&DW in some contexts (Wu et al., 2016). In others it is calculated at 55%, with renovation producing 29% and new construction 16%, while demolition is 8% of the total building activity, renovation 40% and new construction 52% (Bergsdal et al., 2007). Waste generation per gross floor area (WGA) at demolition is reported as being twenty (Bergsdal et al., 2007) or even fifty times more than new construction (Wu et al., 2016). Finally, renovation WGA is estimated at five times more than new construction (Bergsdal et al., 2007). These numbers illustrate the quantitative potential of C&DW and suggest that demolition dominates its production, although renovation also warrants attention.