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Using change detection data to assess amount and composition of demolition waste from buildings in Vienna

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ABSTRACT

Major waste streams in urban areas result from the demolition of buildings. In the case of lack of data on demolition waste generation at the municipal level, the quantity and composition of demolition wastes from buildings can be estimated by multiplying the volume of demolished buildings, which is taken from statistical data sets, by their material composition. However, statistical data sets about the number and thus total volume of buildings demolished are often incomplete. This paper presents an alternative approach to validating demolition statistics (number and volume of buildings demolished) and subsequently demolition waste generation by applying change detection based on image matching to the case study of the city of Vienna, Austria. Based on this technique, building demolition activities not reported to statistical municipal departments can be identified. Results show that in the city of Vienna, demolition statistics yield a total volume of 1.7 M m^3/a demolished building volume, while change detection based on image matching yields a total volume of 2.8 M m^3/a. Consequently, demolition waste generation figures solely based on statistical data probably underestimate the total waste generation, which can have significant consequences for the estimation of landfill space and recycling plant capacity required. For this reason, the approach presented is not only a useful tool for validating existing data on demolition waste generation and demolition statistics, but can also be used when these data sets are not existent at all.

1. Introduction

Waste resulting from construction and demolition activities greatly contributes to overall waste generation in most industrialized societies. The European Commission (2014) estimates that 25–30% of all waste generated in the EU can be attributed to construction and demolition waste (CDW). Due to the high potential to reduce the use of primary resources and landfill space, recycling targets for CDW for all member states were defined by the European Parliament and Council of the European Union (2008). Accordingly, a minimum of 70% (by weight) of non-hazardous construction and demolition waste (soil and stone excluded) shall be prepared for reuse or be recycled or undergo other material recovery by the year 2020. In order to assess whether this target has been reached, data on waste generation and waste flows recycled are required. In the case that it turns out that recycling targets are not met, recommendations can be given to increase the recycling rates in the CDW sector based on the CDW generation data retrieved. Contrary to other waste streams (e.g. packaging waste, WEEE, etc.), CDW management is mostly realized at a regional rather than a national level, and only a very small share of the overall CDW stream (e.g. metals) is subject to the national and international market. The reason is that the mineral fraction, which represents the bulk of the CDW, is characterized by a rather small trade and transport radius due to its large quantity and the low value per mass unit if compared to waste metal scrap, for instance. Hence, regional and local data on CDW generation needs to be established, verified and brought together to obtain coherent information for CDW management and recycling, which in turn is necessary to analyse current practices in managing CDW and to detect optimization potentials.

Demolition waste (DW) from buildings plays a crucial role when it comes to meeting recycling targets for two reasons. On the one hand, buildings are much more diverse in their material composition compared to most civil infrastructure (e.g. roads, railways, pipe

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networks), making potential recycling rates of materials hardly assessable and predictable due to lack of data. On the other hand, in cities, which are the main drivers of material consumption and DW generation in urbanized societies, the bulk of the material stock in the built environment is located in buildings rather than civil infrastructure (Tanikawa and Hashimoto, 2009). Despite this fact, in some countries like Austria, no differentiation between DW from buildings and civil infrastructure is provided in the DW statistics, and thus no information is available to what extent building demolition contributes to overall CDW generation (BMLFUW, 2011).

Research addressing CDW management has resulted in numerous publications in recent years (Yuan and Shen, 2011). The focus of studies ranges from single buildings to global material flow studies of different materials, which in many cases also consider the built environment. The following paragraph distinguishes between studies modelling CDW on a national or regional level and those focusing on methods meant to be applied on a building scale. The methods applied in the studies vary considerably and range from analysing historic statistical data to utilising building information modelling for the prediction of CDW.

Studies focusing on CDW generation on a national or regional level include the work of Hashimoto et al. (2009), where material stocks in buildings and infrastructure and thereof resulting waste streams are estimated for Japan. For the calculation of waste from buildings, the demolished floor space and material per m^2 of floor space are used. Bergsdal et al. (2007) present a procedure to project waste flows entering the Norwegian waste management system so that it meets future requirements in terms of capacity and technical facilities. The model considers different activity levels in the construction industry. Waste generation factors based on stocks and flows of materials are used to estimate the waste amount. Through Monte Carlo simulation uncertainties are considered to make results more robust. Fatta et al. (2003) estimated quantities of CDW for Greece based on the number of demolition licenses and certain assumptions about the amount of waste generated per m^2 demolished building area. The study further focuses on scarcity of suitable landfill space and hazardous substances in CDW. For a large scale region in the United States, Cochran and Townsend (2010) used a material flow analysis approach to estimate CDW based on statistics about construction materials consumed in the past and assumptions about the lifetimes of these materials. Through this approach the CDW amount and composition for the year 2002 was predicted.

Tanikawa and Hashimoto (2009) developed a 4d GIS (geographical information system) to investigate spatial and temporal characteristics and changes in the accumulation of material in buildings and infrastructure. This study focuses more on a regional level investigating two case areas in Japan and the UK. Hu et al. (2010) model input and output flows as well as stocks of the urban residential building system in Beijing city based on a survey of typical residential buildings. For the Lisbon Metropolitan Area in Portugal, De Melo et al. (2011) describe how CDW generation can be estimated based on construction activity and waste load movements of different stakeholders involved in construction activities in the region. The estimation aims at improving CDW management infrastructure and avoiding illegal dumping in the region.

Studies focusing on a building level include Solís-Guzmán et al. (2009), who developed a model to estimate the amount of waste generated during both construction and demolition. The model is based on the investigation of the bill of quantities and coefficients to estimate demolished volume, wreckage volume, and packaging volume. The model was applied to two case studies (one construction and one demolition project). Cheng and Ma (2013) facilitate building information modelling (BIM) to estimate building materials. Their system allows extracting information about materials in single buildings and estimating waste amounts to efficiently plan recycling and reuse procedures and to calculate disposal fees. They apply their method to a building in Hong Kong. A prerequisite for the application of the method is that all relevant materials of the respective building are recorded in BIM.

While in many of the studies mentioned a lot of effort is put into developing models to simulate material stocks and flows in the built environment, the basis of the calculation, e.g. material composition of buildings, often seems not to be considered of equal importance. Moreover, the actual lifetime of buildings depends on numerous factors, making reliable predictions about average lifetimes almost impossible and thus calls into question the overall applicability of building models based on lifetime assumptions (Kohler and Yang, 2007). In addition to that, the decoupling of CDW management from its regional context appears inappropriate as long current management practice remains at a local level. In order to generate data on the amount and quality of DW occurring in a city, detailed knowledge on the material composition of buildings, on the one hand, and about the demolition activity, on the other, is required. As shown in Kleemann et al. (2014), however, the quality (incl. completeness) of statistical data on the material composition of DW from buildings is often poor. With regard to data on demolition activities, only rudimentary documentation is frequent. Consequently, alternative approaches to generating data on DW generation and composition are required in order to assess the quality of existing data. Thus, the objective of this article is to present such an alternative, and, to our knowledge, a novel approach, exemplarily applied to the case study of the city of Vienna, the capital city and cultural and economic centre of Austria, with about 1.8 million residents (representing around 20% of the population in Austria). The study at hand aims at estimating the amount and composition of DW generated through demolition activities in the building sector. Information about the demolition activity is based on statistics (Subsection 2.1) and on data derived from remote sensing techniques, which is a data source that has so far not been used to verify reported DW quantities (Subsection 2.2). The generation of data on the specific material intensities of different building categories through different approaches is explained in Subsection 2.3.

2. Materials and methods

Different data sources are used in this study to estimate the amount and composition of waste resulting from building demolition. The demolition activity (demolished gross volume [m^3]) of different building categories in Vienna is evaluated based on (i) statistics and (ii) image matching based change detection data. Subsequently, specific material intensities (kg/m^3 gross volume) for 15 different building categories (which discriminate between construction period and utilization) are assigned to the demolished building volume of the respective categories to assess the amount and composition of the demolition waste. All data sources are processed in a GIS model. Fig. 1 summarises the data generation approach schematically, which is described in more detail in the following subsections.

2.1. Statistics-based analysis of the demolition activity

The demolition statistics provided by the municipal building authority (MA 37) is based on the collection and documentation of demolition notifications and contains only information about the address of the buildings being demolished, but not about any features of the respective building itself. Hence, in order to obtain data about the size and type of each building, different municipal GIS data sets are combined. The data set, provided by the municipal department for urban survey (MA 41), contains terrestrially and