Zurich, June 15-17 2016
Sustainable Built Environment (SBE) Regional Conference

Expanding Boundaries:
Systems Thinking for the Built Environment

COMBINING GIS DATA SETS AND MATERIAL INTENSITIES TO ESTIMATE VIENNA'S BUILDING STOCK

F. Kleemann[1]*, J. Lederer[1], H. Rechberger[2], J. Fellner[1]

[1] Christian Doppler Laboratory for Anthropogenic, Technische Universität Wien, Karlsplatz 13/226.2, 1040 Wien, Austria

[2] Institute for Water Quality, Resource and Waste Management, Technische Universität Wien, Karlsplatz 13/226.2, 1040 Wien, Austria

*Corresponding author; e-mail: fritz.kleemann@tuwien.ac.at

Abstract

The work presented describes a method to analyse the current material stock in buildings in the city of Vienna as a basis for estimating current and future demolition waste available as potential secondary raw material. The assessment of the material stock in buildings is carried out through combining data about the material composition of different building categories and information about the building structure. Data about the material composition of buildings is generated by investigating single buildings (case studies), analysing construction files of demolished buildings, evaluating available documents of newer buildings (tender and billing documents, LCA data), and through literature review. As a result, specific material intensities for different building categories (construction period/ utilization) are merged in a database which is continuously enhanced with ongoing research. In order to characterize the building structure of Vienna, GIS data from different municipal departments are used. A data set providing information about gross volume, construction period, and utilization is generated. By combining information about the building structure and the specific material intensities of different building categories, the overall material stock embedded in buildings in Vienna was calculated to be 380 million tons, which equals 210 tons per citizen. Combining the data about the embedded materials with information about demolition activities will allow estimating current and future amounts of demolition waste and thus materials potentially available for recycling. Knowledge about the material stock and flows of buildings is an important step towards closing material cycles in demolition waste management.

Keywords:

building material; building stock; geographic information systems (GIS); industrial ecology; urban metabolism; urban mining

1 INTRODUCTION

Recent years have shown an increasing interest in the building stock as a research object (Kohler and Hassler, 2002). Different studies have determined the gross volume, the built-in materials, and the age as well as renovation intervals of buildings in order to estimate the demand for heating and cooling of buildings or renovation requirements of old structures. Within the life-cycle of a building, all these examples can be allocated to the use phase. A different perspective on the building stock is to focus on the end-of-life phase, particularly the projection of the quantity and quality of construction and demolition wastes (CDW). This approach considers the building stock as a future anthropogenic resource deposit for secondary raw materials (Bergsdal et al., 2007; Hashimoto et al., 2009).

The built environment in Austria has only been estimated on a national level so far using statistical data (Stark et al., 2003). The chosen top down approach combines different data on the use of construction materials (mineral, organic, metallic). Even though the use of statistical data sets, as utilized in most

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_44, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

international studies, allows determining the overall stock size as well as the gross-generation of CDW, localizing material stocks and sources of CDW is not possible. The latter however is of major importance for the management of these wastes, as their recycling (except for metals) or disposal has to take place within the region of generation (distance of 20 to 40 km), as otherwise transportation costs would be too high. In this work the spatial information of the built environment has been added by employing GIS (geographical information system) data.

The study at hand was carried out in Vienna, the capital city and cultural and economic centre of Austria with about 1.8 million residents (representing almost one quarter of the national population). It presents an approach for analysing both the building structure and the material stock in buildings in Vienna. The building structure is analysed by combing different GIS data sets, which allows localizing different building categories. Data on the material intensity of different building categories, including bulk materials (e.g. minerals) and relevant materials in lower concentration (e.g. wood, plastics, metals, asbestos) is generated through various sources and approaches, ranging from the analysis of documents and on-site investigations to the review of relevant literature. The study aims at mapping information about the material stock in buildings in the city of Vienna as a basis for efficient resource management such as projecting the flow of wastes and secondary raw materials from demolition activities in the building sector.

2 METHOD

The present study combines different approaches to analyse the building structure in Vienna with regard to size (gross volume – GV), construction period, and utilization, as well as to generate a database about the material intensities (kg/m³ GV) of different building categories (differentiated by construction period and utilization). Subsequently, data on the building structure and material intensities of different building categories are combined to assess and localize the material stock in all buildings in Vienna.

2.1 Building structure

The aim here is to generate a city-wide GIS data set which comprises information about gross volume (GV), construction period, and utilization for each building. To achieve that the following steps are conducted:

1. A map of the municipal department for surveying includes information about area and relative height* of each building/building part in Vienna. The data is based on terrestrial measurements.
2. To assign information about construction period and utilization a map of the municipal department for city planning and land use is spatially joined with the above mentioned map.
3. Existing data gaps with regard to construction period and utilization for some areas of the city are filled using information of the municipal department for city development and planning (for construction period) as well as the general zoning plan (for utilization).
4. Data about new buildings (built after 2008) is added trough data administrated by the municipal building and inspection department.

   **The relative height is the distance between ground level and eaves. Therefore, the average height of roofs and basement floors was added based on expert judgements. Depending on the building categories different additional heights were assessed.*

Altogether 15 categories, differentiating between construction period and utilization of buildings, are distinguished: 5 different construction periods (before 1918, 1919-1945, 1946-1976, 1977-1996, after 1997), which correspond to the available GIS data, and 3 strongly aggregated categories for utilization (residential, commercial, industrial).

2.2 Material intensities

As the material composition of buildings varies depending on utilization and construction period, specific material intensities per GV can be determined and assigned to different building categories.

As described in Kleemann et al. (2014) demolition projects in Vienna are investigated and built-in materials are quantified prior to the demolition of the building, based on the analysis of available documents (construction plans, expert´s reports) and on-site investigation, including selective sampling. During the on-site investigation, data on built-in materials are collected through labour intensive measurements and selective sampling (weighting, and measuring of components such as windows, doors, partitions, ceiling suspensions, floor and roof constructions, wires, pipes, etc.). Based on the data collected, information about the different built-in materials is aggregated and the mass is calculated based on volume, area or number of the particular material as well as on data on its specific density or weight.

In order to increase the sample size of buildings investigated, construction files of buildings reported to be demolished in the city of Vienna are analysed. Depending on the quality of the documents, building materials used for wall, ceiling and sometimes also for roof or floor construction can be determined. Data gaps,

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_44, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

mostly regarding low volume materials (installations, fittings, windows) are filled by using specific material intensities obtained from the case studies analysed in detail.

In order to complete the data set on the specific material intensities with regard to newer buildings, which are rarely demolished, existing data on the material composition of these buildings is utilized. This material data is derived from life cycle assessments (LCA), tendering documents, construction plans and accounting documents of recent building projects. To put the material intensities generated in context with other studies carried out, literature data on the material composition of buildings are utilized.

3 RESULTS AND DISCUSSION

3.1 Building structure

The overall GV of buildings in Vienna is about 860 million m³, with a large share being used for residential purposes (540 million m³ GV). With regard to the age of the building stock, it is noticeable that the largest share of buildings was constructed before 1918 (290 million m³ GV). Figure 1 illustrates the distribution of the GV among the different building categories.

3.2 Material intensities of different building categories

The combination of all data collected and analysed resulted in specific material intensities for different building categories. The general structure of the data and aggregated results are shown in Table 1. The material categories (mineral, organic, metal) are further divided in specific materials such as concrete, bricks, glass, asbestos, wood, plastics, bitumen, iron, aluminium or copper.

Not surprisingly Table 1 indicates a dominant share of mineral materials within buildings. In contrast organic materials and metals occur in rather low concentrations. Newer buildings tend to have higher metal contents (mainly because of reinforcement steel) and a lower content of organic material (mainly due to a decreasing usage of wood). No information could be gathered for industrial buildings built after 1997 using the described approach. For the calculation of the material stock in buildings, values from the previous time period were used.

3.3 Overall material stock and its spatial distribution

By combining information about the building structure and the specific material intensities of different building categories, the overall stock in buildings in Vienna (380 million t) was calculated. Around 96% of the material is mineral, mainly represented by concrete (150 million t), and bricks (130 million t) and mortar (50 million t). Organic materials and metals hold a small share (4%) of the overall material stock in buildings, of which wood and steel are the dominant materials (Figure 2)

The material stock in buildings per capita is about 210 t. As Vienna is an economic centre in Austria with around 250,000 commuters, a part of the building stock also services people residing outside Vienna. From a resource and waste management perspective, the spatial distribution of materials is of interest. This information allows predicting CDW arising through the demolition of buildings as well as projections of secondary raw materials arising from C&D activity on a municipal level. Combining GIS data with specific material intensities further allows the establishment of a resource cadastre, which illustrates the spatial distribution of materials throughout the city. Figure 3 shows the material intensity of buildings in Vienna expressed as mass of wood per built-up area of the buildings.

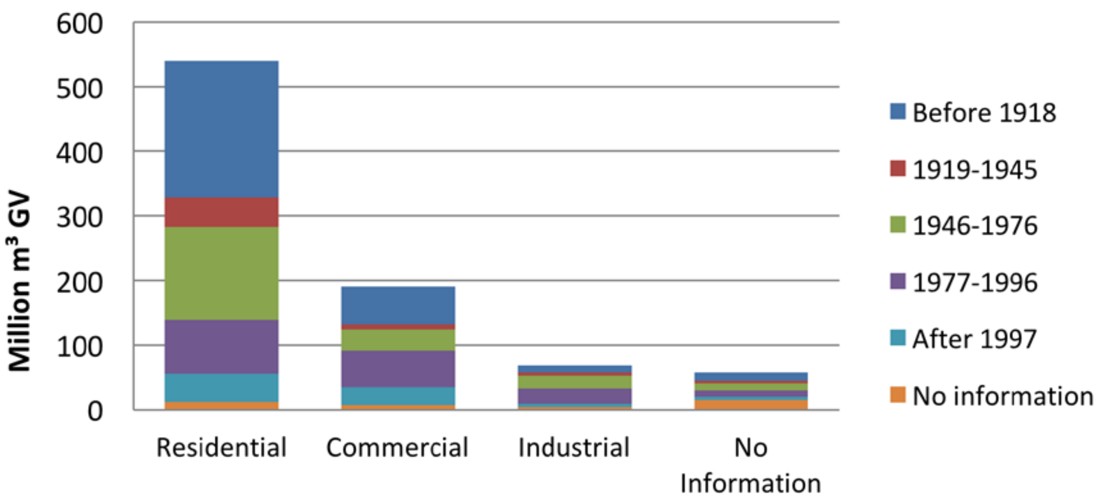

Figure 1: Distribution of GV in Vienna among the different building categories (kg/m³ GV)

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_44, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

Period of construction	Utilization	Mineral materials	Organic materials	Metals	Total
Before 1918	residential	390	19	3,1	410
	commercial	430	3,7	4,4	440
	industrial	280	5,8	8,8	300
1919-1945	residential	410	13	4,8	430
	commercial	340	7,1	6	360
	industrial	320	28	5,8	350
1946-1976	residential	430	6,5	7,3	450
	commercial	350	7,6	5,7	360
	industrial	340	7,6	13	350
1977-1996	residential	430	6,7	7,1	460
	commercial	380	1	13	400
	industrial	170	1	15	180
After 1997	residential	380	10	15	410
	commercial	320	5,7	10	340
	industrial	290	5,6	13	310

Table 1: Specific material intensities of different building categories (Kleemann et al.*, 2016).*

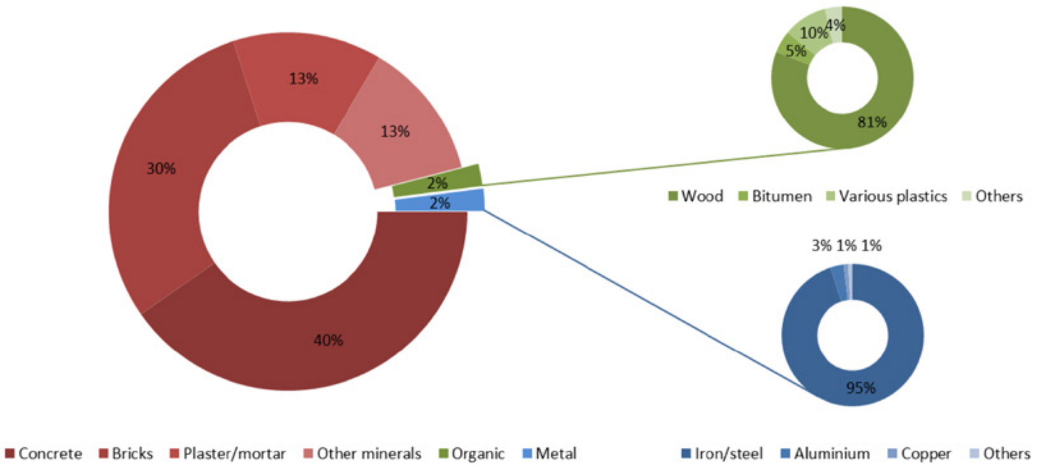

Figure 2: Material composition of Vienna's building stock (Kleemann et al.*, 2016).*

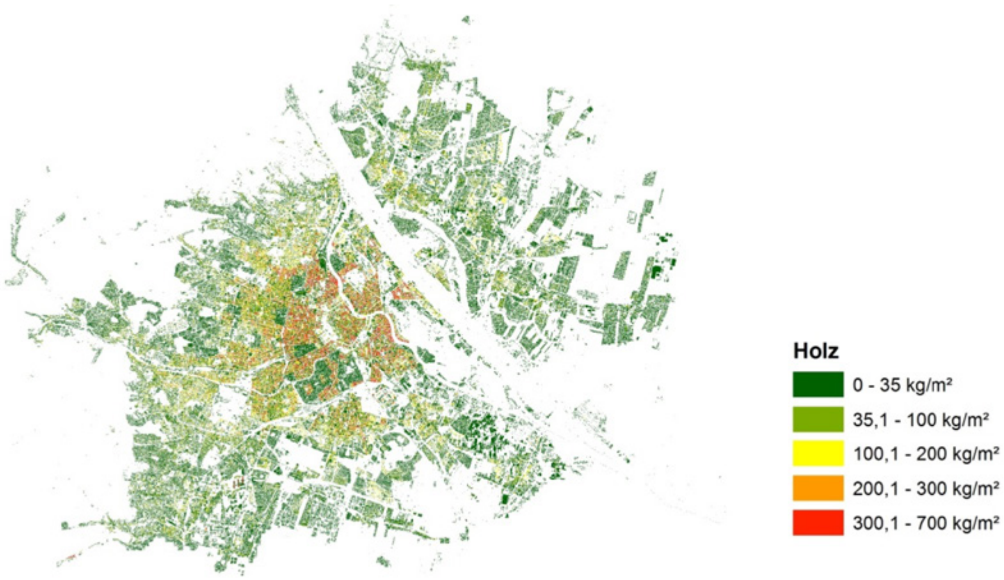

Figure 3 Spatial distribution of wood in the city of Vienna (kg/m² built-up area).

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_44, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

4 CONCLUSIONS AND OUTLOOK

The results demonstrate that it is possible to characterize the material composition of the building stock by combining available GIS data sets with collected data on the material intensity of different buildings categories. Combining the generated data about the material stock with information about the demolition activity in Vienna will further allow assessing the amount and composition of CDW and thus also the materials potentially available for recycling. The data basis on specific material intensities of different building types will be improved with ongoing research in this field.

5 REFERENCES

1. Bergsdal, H., Bohne, R.A., Brattebø, H., 2007. Projection of Construction and Demolition Waste in Norway. Journal of Industrial Ecology 11, 27-39.

2. Hashimoto, S., Tanikawa, H., Moriguchi, Y., 2009. Framework for estimating potential wastes and secondary resources accumulated within an economy–A case study of construction minerals in Japan. Waste management 29, 2859-2866.

3. Kleemann, F., Lederer, J., Aschenbrenner, P., Rechberger, H., Fellner, J., 2014. A method for determining buildings' material composition prior to demolition. Building Research & Information, 1-12.

4. Kleemann, F., Lederer, J., Rechberger, H., Fellner, J., 2016. GIS-based analysis of Vienna's material stock in buildings. Journal of Industrial Ecology (in press).

5. Kohler, N., Hassler, U., 2002. The building stock as a research object. Building Research & Information 30, 226-236.

6. Stark, W., Vogel-Lahner, T., Frühwirth, W., 2003. Bauwerk Österreich–Endbericht. GUA - Gesellschaft für umfassende Analysen GmbH, Wien.

G. Habert, A. Schlueter (eds.): Expanding Boundaries © 2016 vdf Hochschulverlag AG an der ETH Zürich
DOI 10.3218/3774-6_44, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html