Subway Infrastructure: Waste Flows and Stock Changes in Refurbishment

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INTRODUCTION

The main objective of the paper at hand is to investigate material and waste flows, and stock changes of subway infrastructure associated with its refurbishment. Specific attention is given to the relation between recycling, reuse and virgin material flows in a case study. Furthermore, the extent to which policy targets are achieved in a specific refurbishment process is investigated. Thereto the refurbishment of a subsection of Vienna's subway network was chosen as a case study. To fulfil the objective a bottom up material flow analysis (MFA) of the refurbishment process on the subsection was performed. For the investigation, the materials were assigned to the three main categories mineral (e.g. gravel, stones, concrete, soil), organic (e.g. wood, plastics) and metals (e.g. iron and steel, aluminium, copper). These general categorizations represent both materials that make up the bulk of the total material input, material output and stock (i.e. mineral) as well as materials having a high secondary raw value (Lederer et al., 2016). For the investigation real inventory data from the public transport provider (Wiener Linien GmbH & Co KG) was used. Due to legislative and policy changes at the urban, national and supra-national level ((EUROPEAN PARLIAMENT AND OF THE COUNCIL, 2008; City of Vienna, 2014; BMLFUW, 2016)) aimed at decreasing resource consumption by means of a circular economy, the study focuses on the reuse of construction elements and the utilization of recycling construction materials. In terms of mass, construction and demolition activities are among the biggest sources of waste in Europe (construction and demolition waste (CDW). They account for approximately 25% - 30% of all waste generated in the EU and consist of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, and excavated soil, many of which can be recycled. In order to tackle this challenge, the recycling of construction and demolition waste is encouraged by an EU-wide mandatory target of 70% (European Commission, 2015). Policy objectives are important. Yet in order to meet these objectives, the use of recycling building material, at best produced by demolition material of the construction site, is crucial to increase recycling material rates and to promote the substitution of virgin building material. Also important are specific actions taken on construction sites in terms of the reuse of construction elements, which represents another important policy objective expressed e.g. by the waste hierarchy. The extent to which these policy objectives are already fulfilled within the case study are demonstrated.

MATERIAL AND METHODS

The method used to answer the research questions is a bottom-up material flow analysis (MFA). All material flows are presented in the mass unit "metric ton (t)"; and the reference period selected is one year (2016). Three material categories are considered: minerals, organics and metals. First, the material stock of the subsection investigated was calculated using the same bottom-up approach as applied by Lederer *et al.*, (2016). Thereafter, publicly available data from literature was used together with articles and books that described the subway network, especially those parts based on the former Stadtbahn (Gerlich, 1980; Hinkel, 1982; Schlöss, 1987; Duniecki *et al.*, 1991; Lederer *et al.*, 2016). In addition, data from the operator, i.e. current and historic construction and engineering plans of construction elements, buildings and track bed were all used. In the second step, the flows of built-in materials and recycling materials/wastes were calculated. Thereto company data were used. To clarify and complete some of these data, expert interviews with persons in charge for the specific refurbishment process were conducted. The system investigated is the subway network in Vienna, with five subway lines totalling 87 kilometres in length, including main and shunting tracks. A subsection of the line U4 was refurbished in 2016. The refurbished part consists of parts of the line constructed in the 1890s, of which some parts (station buildings, viaducts) are cultural heritage monuments. In the paper at hand, this rehabilitation process over a total length of 3,500 m was investigated in terms of stock changes and material input and material output flows.

RESULTS

The overall material stock of the subsection investigated was around 360,000 t. The by far biggest part could be assigned to the material category minerals (~97%), followed by metals (~3%), and organics (<1%). For the material and waste flows in total 22 different material categories were considered. In terms of mass, the main materials brought into the system were gravel (57%), concrete (30%), and asphalt (11%), all of which are related to the category minerals. Around 400 t of metals were built in the subsection, of which around 73% were iron/steel,

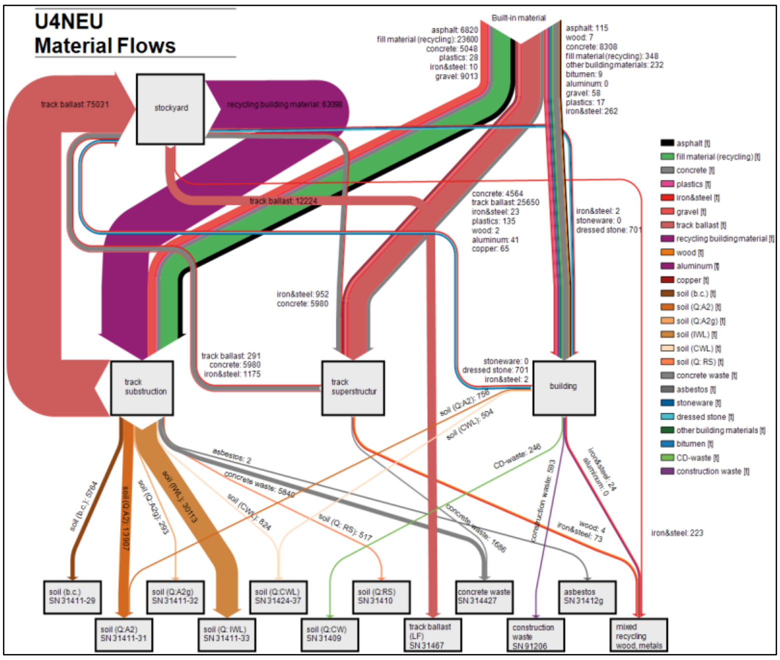

Figure 1: Material flows during the refurbishment of the line U4 (U4New)

16% copper, 10% aluminium, and <1% others. In terms of mass, however, the usage of metals (<1%) is negligible. The main part of the built-in materials was used for the track substructure (53%), followed by track superstructure (36%), and buildings (11%) (see Figure 1). Around 74,000 t were demolished and removed from the construction site and brought to landfill, waste treatment, or recycling facilities. Since the amount of built-in material was considerably larger than the material removed, the overall material stock increased by around 11,000 t. Per meter of track the value rises by 3 t/m to around 110 t/m. For the overall material input, a significant share of construction elements were also reused (mainly railway sleepers including rails). Moreover, an even larger amount of materials was recycled on-site. This material remained within the section with either the same or a different function.

Discussion and Conclusions

Within the refurbishment process, in total material with a mass of around 155,000 t was built into the system. The share of recycling material was significantly higher than the use of virgin material. In detail 39% virgin construction material, 15% recycling construction material, 41% on site-recycling construction material and 5% reuse construction components were built into the section. Regarding the policy objectives (e.g. BMLFUW, (2016); City of Vienna, (2014); Eisenmenger et al., (2015)), it can be stated that the target to reduce the usage of virgin building materials was reached in the case study investigated. In fact, in terms of overall built-in materials, 15% recycling material, 41% on-site recycling material and 5% reused construction elements were used. Hence, the share of virgin construction material built-in was below 40%. Furthermore, the results of the present study show that the refurbishment process increased not only the overall material stock but also its complexity. The waste flows (Figure 1) indicate a removal of historical bulk material (soil in various qualities). Such materials always carry the risk of being polluted through the more than 100-year use phase. Even if no significant amounts of pollutants were found, the economic and environmental risk could be reduced through the rehabilitation. After the refurbishment, the rail bed is uniform in structure, which simplifies future maintenance and future renewal. The material intensity and material compositions in the section investigated has increased. This is especially true for components of the open track in particular the track substructure, whereas in the stations mainly building components were replaced with equal materials. Within the open track, the material intensity and composition changed significantly within the track substructure, however, remained unchanged within track superstructure. Because the track superstructure was built in the 1970s and has been continuously updated in recent years. The track substructure was not changed in the 1970s and is not state of technology. The newly built substructure has a significantly stronger subgrade layer and frost protection layer (mainly from recycled material). Additional layers, for instance, a continuous bituminous base layer as a moisture seal, were added to the substructure. Consequently, there was an increase in both the material intensity and material diversity.

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