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Circular planning: the case of Amsterdam

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Abstract. Circularity is an increasingly often mentioned ambition of governments of various levels, yet the translation into concrete plans and policies is limited. The Metropole Region of Amsterdam (MRA) is a pioneer in this field, initiating a research for circular rebuilding of a neighbourhood in 2016 and the development of a roadmap for circular urban development in 2017. This year, the port of Amsterdam and the municipalities of Amsterdam and Haarlemmermeer together commissioned the analysis of the effects of circular construction on material flows, transport movements in the MRA, and land use in the harbour area. These effects were analysed by means of a building material model (BOB), combined with logistic models and construction and demolition forecasts of the Economic Institute for Construction and Housing (EIB). The results showed a mismatch between the supply of secondary building materials and the construction demand, ranging from factor 7 (more demand than supply) in the coming years to a factor 4 in the period 2041-2050. An evaluation of circular construction concepts revealed high potential for the reuse of structural elements, leading to a 20% decrease of material need for new buildings, 21% less transport kilometres and 20% less land use. The concept of demountable constructions was calculated to have no impact on total material use between 2018-2050, while increasing the transport kilometres and land use. Several concrete recommendations were given, for example on the interaction between logistics and land use and need for a more in-depth comparison of a variety of circular strategies.

Keywords: construction and demolition waste, circular economy, built environment, urban planning, urban metabolism, transformation strategies

1. Introduction

Today, more than half of the global population lives in cities and this number is expected to increase steadily in the coming decades [1]. This accumulation of people puts high pressure on policy makers and urban planners regarding of housing, public transport, commodities and many more.



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An increasing number of cities is looking for quantitative insights in their building material flows in order to get grip on (circular or sustainable) building practices. Universities and knowledge institutes are developing building stock models to estimate the demand of primary and/or secondary building materials and create insight in the building material flows (overview by [2]).

While most of these models provide insight in current material stock and some reach out to expected future material flows (for example [3]), there are no major analyses of building scenarios in relation to material flow analysis, logistics and spatial planning. Therefore, the effects of novel building practices (e.g. circular building concepts) on environmental impacts and land use in cities are barely known.

The Metropole Region of Amsterdam (MRA) is an example of an urban area with a large construction and spatial planning challenges the coming decades. The MRA has to the ambition to build 250,000 residential dwellings, realise a large amount of non-residential buildings and construct, maintain and replace infrastructure. For these construction and transformation activities the MRA wants to incorporate the national goals of circular building practices [4]. These ambitions heavily affect the building material demand, land use in the surrounding industrial and harbour area and the intensity of road use.

This study aimed to indicate the impacts of these ambitions of the MRA. The demand and supply of (secondary) building materials from 2018 to 2050 were analysed. Additionally, the effects of transport movements and land use in the harbour area were researched for two circular scenarios in comparison to the current situation.

2. Methodology

This research was divided in two stages: an inventory stage and a scenario stage. In the inventory stage, construction forecasts, a urban stock and logistic model were linked to each other. In the scenario stage, the models were used to compare two future scenarios relevant for the MRA: reuse of structural elements and use of dismantlable constructions.

2.1. Inventory stage: used models

The material flows were modelled by means of the *BOB* model (for example, see [4]). *BOB* is a construction & demolition waste (CDW) radar model which can be used to estimate the future demand and supply of (secondary) building materials. The input data consists of generic building profiles in combination with various public datasets on the building and infrastructure stock (e.g. cadastral information). The outcome of the model is a balance of building materials used in infrastructure, residential and non-residential dwellings. Sand, debris and other materials for the foundation of buildings and roads are out of the scope of the model.

The Economic Institute for Construction and Housing created construction and demolition forecasts for each building type (residential and non-residential buildings and infrastructure) using a model based on demographic and economic indicators. The forecasts were constructed at municipality level for four timesteps: 2018-2020; 2021-2030; 2031-2040 and 2040-2050.

The transport movements were estimated for the largest flows of building materials: bricks, concrete (both prefabricated and as mortar), cement and debris. Combining the material flows, distances from the centre of the municipalities to the nearest fabrication plant and required number of vehicles made it possible to calculate the amount of transport movements, the total transport distance and corresponding carbon dioxide emissions.

The land use requirements were calculated based on company information. The Port of Amsterdam houses a significant part of the construction related companies that are active in the region, like concrete producers, but also painters and plasterers. Based on the area used by concrete producing and building demolition waste treatment facilities, the future need for land in the harbour area was qualitatively estimated.

2.2. Scenario development

To show what the impact the implementation of circular construction methods could be on material flows, transport movements and land use, two circular scenarios were compared with the ‘current situation’ (business as usual). For the current situation was presumed that only primary materials are used for construction and that after demolition building materials are assimilated as debris. The first circular scenario focusses on reusing construction elements of current building stock and will be referred to as “circular reuse scenario”. It was presumed in this scenario that 30% the structural construction are technically, ecologically and financially suitable to be reused.

In the second scenario the concept of ‘design for disassembly’ is implemented in the construction of new buildings, such that these can be easily dismantled at the end of their life. It will be referred to as the “circular demountable scenario”. In this scenario is only focussed on the largest materials flows: concrete, bricks and cement screed and presumed that cement screed cannot be demounted, since it is used in floors and foundation, that bricks can be produced such that they clicked on top of each other and that part of the mortar concrete is replaced by prefabricated elements.

For both scenarios the influence on the demand and supply of building materials, transport movements and land use is researched. Note that for the second (circular demountable) scenario, only the effect of the construction phase are reflected in the results. Since the deconstruction of these buildings will take place after 2050, the positive effects at the end of the life are not reflected in the material flows, transport movements or land use.

3. Results

3.1. Material flow analysis

The result of the building material flow analysis for the current situation is shown in Figure 1. In this figure the large gap between the supply of and demand for construction materials is clearly shown. The disparity slightly decreases over time due to, on one hand, the stabilization of the demand for new constructions (buildings and infrastructure) resulting in a light decrease in building material demand from 3.1 to 2.7 Mton/year. And, on the other hand, the increase in the supply (i.e. expected demolition.) from 0.45 to 0.7 Mton/year. As a result, the total demand for materials is in the first coming period (2018-2020), seven times larger than the supply of secondary materials, whilst in the period 2041-2050 this difference reduces to four times. Hence, the reuse of demolition waste could be a valuable resource to reduce the material demand of the construction sector. However, the large-scale implementation of “100% circular constructions”, without any primary raw materials, is not feasible the coming decades.

Figure 1 also provides insight in the potential for reuse of each material. For concrete, which is the largest material flow in demolition as well as in construction, the supply of secondary materials can cover up to 22% of the demand for new constructions in the first coming period (2018-2020). For bricks and cement screed, the maximal supply from demolition projects could be 29% in this period. However, these values are explicitly denoted as “maximal potentials” because with the current demolition techniques it is still impossible to achieve 100% effective reuse of materials. The realized reuse figures will thus be lower than the mentioned percentages above.

Nevertheless, although a 100% circular construction sector seems far from realistic, even a “less linear” economy could create large impact, since the construction sector accounts for large resource consumption, greenhouse gas emissions and waste production. For example, in 2010 the Dutch construction sector emitted 6,5 Mton of CO₂ equivalents for the production of raw materials and an additional for 1,7 Mton of CO₂ for their transport [5]. A reduction of 25% would thus lead to a reduction of 2 Mton of CO₂ equivalents annually, which equals 6 billion (6 x 10⁹) kilometres driven in a passenger car (based on emission of 0.334 kg CO₂ eq./km calculated with LCA software SimaPro 8.5.2 from

ecoinvent (3.4) “Transport, passenger car {RER}| market for | Cut-off” by means of the IPCC GWP100a method).

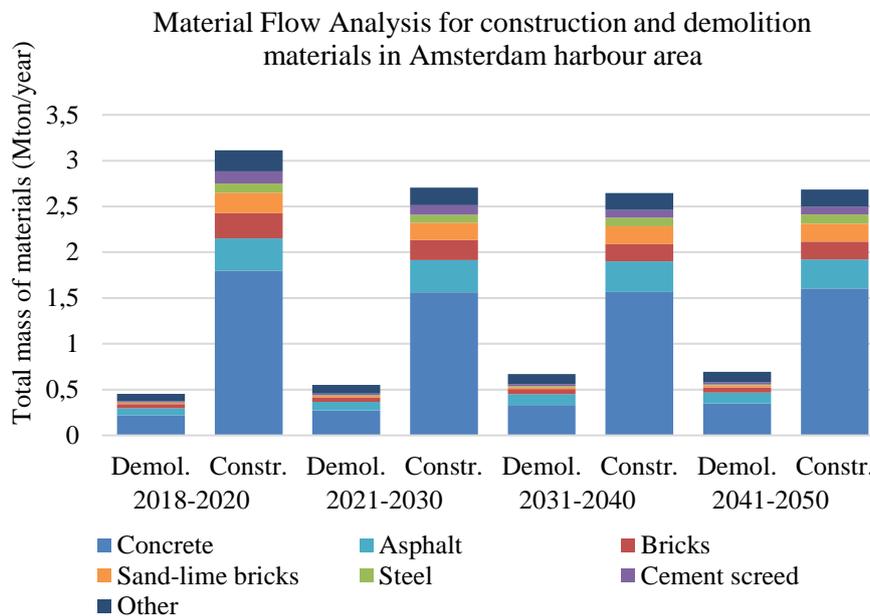


Figure 1. Average annual amount of I) secondary building materials from demolition (“Demol.”), and II) demand of building materials for construction of residential and utility buildings, infrastructure and drains (“Constr.”) in the Amsterdam harbour area. Annual amounts are calculated over a 10 year period, except the first period of analysis (3 years).

The circular reuse scenario will reduce total mass of new building materials with 20% and supply of debris with 36%. The material flow of the circular demountable scenario will not change, since the changes in implementation of bricks and concrete the total demand of materials is the same.

3.2. Transport movements

A logistic model was used to calculate the differences in transport need (expressed in vehicle kilometres driven) between the two circular scenarios and the current situation. The result of this comparison is shown in Figure 2. The figure shows that the circular reuse scenario, in which the structural elements of buildings are reused in the construction of new buildings, results in a 21% decrease of vehicle kilometres driven in comparison to the current situation. This decrease is a direct result of the reduction in need for virgin material and production of debris, thus transport to and from construction sites. In total, it leads to 50,000 less transport movements.

The circular demountable scenario, in which the concept of design for disassembly is applied, results in a sharp increase of transport: 11% more vehicle kilometres than the current situation. This increase is caused by use of more concrete prefabricated elements (instead of pre-cast construction methods) and the lower load factor of these elements compared to mortar. In addition, it results in an additional 74,000 transport movements a year.

3.3. Land use

The land use analysis leads to similar conclusions as the logistic analysis, as can be seen in Figure 3. The circular reuse scenario results in a decrease in land needed by about 20%. This decrease is caused by a lower supply and demand of concrete compared to the current situation, and thus smaller production

and waste treatment facilities. In circular demountable scenario, the land use increases with 13% due to the larger number of prefabricated elements used during the construction and fact that the production of prefabricated elements requires more space than the production of concrete mortar.

Not shown in figures 2 and 3, is the effect over time. It was analysed that both circular scenarios show the same patterns over time as the current situation. In the current situation, the land use increases by about 10% over the years, including a decrease (9%) of space needed to produce concrete due to a decreasing material demand, and a significant increase (~50%) of space needed for demolition waste treatment facilities related to increased demolition as calculated by the EIB.

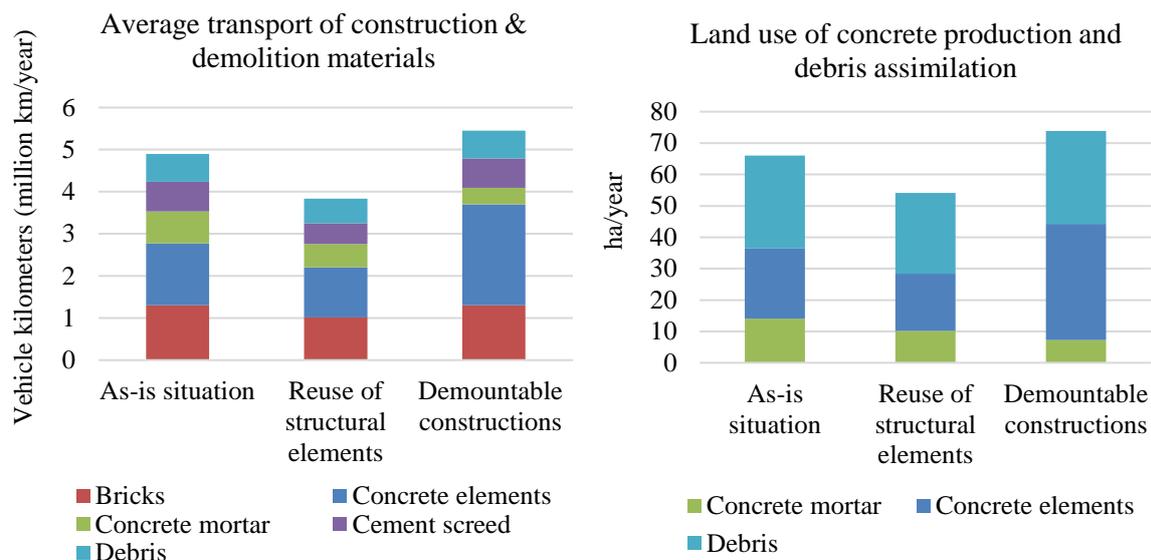


Figure 2. Average annual amount of vehicle kilometres for transport of construction and demolition materials in the Amsterdam harbour area.

Figure 3. Average annual amount of land needed for concrete production and debris association in the Amsterdam harbour area.

4. Conclusions and limitations of the study

4.1. Conclusions

In this study, the annual supply of secondary building materials in the MRA was estimated to increase from 0.45 Mton now to 0.7 Mton around 2041-2050. Compared to the demand for building materials, this supply is now (at least) seven times lower. In time this mismatch will decrease to four times. Hence, it is virtually impossible to create fully regenerative cities, but potentially the primary building material demand and its corresponding environmental and carbon footprint can be reduced with 25% by using secondary materials.

The evaluation of circular construction scenarios showed that not every circular strategy is beneficial in terms of material use, transport burden and land use. The evaluation revealed high potential for the reuse of structural elements, leading to a 20% decrease of material needed for new buildings, 22% less transport kilometres and 20% less land use. On the other hand, the concept of demountable constructions was calculated to have no impact on total material use between 2018 and 2050, while transport kilometres and land use increased 14% in comparison to the reference situation. Note that the positive effects of demountable construction at the end of the life of building will occur after 2050 and thus out of scope of this study. This results show that not all circular concepts reduce environmental or societal impacts: some might actually increase impacts and could be considered less sustainable than the current, linear practises. To conclude, this analysis shows the importance of an integral assessment of novel

concepts, meaning not only to focus on one impact category (e.g. material reuse) but scoping systems as a whole, including transport, land use and other environmental or societal aspects.

4.2. *Limitations of the study*

In this study, several models were linked to gain insights in the future supply and demand of construction materials, transport movements and land use impacts. For this macroscale analysis, the models based on, among others, average building materialization and national demographic trends are well applicable. However, this approach is not suitable for analysis on a smaller time and geographical scale, e.g. the effect of circular building practices on local air quality of inner cities.

Not only the models, but also the interpretation of the results knows some limitations. By making a comparison of supply and demand of (secondary) building materials, actually the absolute theoretical maximum reuse potential is showed and it is not taken into account that only a part of the materials from current building stock can be reused. E.g. the supply of mixed or contaminated demolition material flows and technical barriers in the recycling (with what efficiency is it possible to reuse concrete in new concrete?) limit the reuse of materials.

The concepts studied in this paper were theoretical cases with a limited number of parameters included. For the successful implementation of circular construction concepts, more aspects should be considered and preferably tested in real case study projects. Important aspects are for example, the financial situation (for whom is it economically viable to separate bricks and cement by hand), quality & liability issues (when and what to inspect? How to guarantee the quality of secondary building materials?) end environmental assessment of (recycling) technologies (is it *really* better for the environment to reuse material considering all the additional reprocessing steps?).

5. References

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