Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
## Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

### Personal information

<table>
<thead>
<tr>
<th>Name</th>
<th>Charley Meyer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student number</td>
<td>4208811</td>
</tr>
<tr>
<td>Telephone number</td>
<td>0655387636</td>
</tr>
<tr>
<td>Private e-mail address</td>
<td><a href="mailto:charleymeyer@hotmail.com">charleymeyer@hotmail.com</a></td>
</tr>
</tbody>
</table>

### Studio

| Name / Theme                  | Building Technology; critical materials + BIM |
| Teachers / tutors             | David Peck, Boris Bähre,                     |
| Argumentation of choice of the studio | During the bachelor ‘Bouwkunde’ I noticed I wanted to focus more on the technical aspects of architecture, which made me choose the Master Building Technology. Building Technology is the most technical track among all Architecture Masters. Optimizing designs by applying technical knowledge is in my opinion a very valuable task. Therefore, the building technologist is important to realize integrated designs and create a bridge between the architect and the engineer. |

### Graduation project

| Title of the graduation project | Optimization of critical materials in the built environment using Building Information Modelling (BIM) |
| Goal                           |
| Location:                      | The Netherlands |
| The posed problem,            |
| Based on the preliminary described background, the problem definition can be described in threefold: |
| 1. The materials needed to realize the energy transition of the built environment towards energy efficient buildings and renewable energy technologies are critical; the risk of a disruption is high, while they are highly important for our current economy. |
| 2. Criticality of the materials seems to be an unknown field in the built environment, while we strongly rely on them. |
| 3. Information about stocks and flows of critical materials is needed; data is missing or only available in dissimilar datasets. |
**Research questions**

Based on the described objectives, the main research question of this research is formed:

*Is BIM as an approach compatible to facilitate knowledge and solutions for critical materials in the built environment?*

The main question consists of two parts: the first part focuses on knowledge and solutions for critical materials in the built environment. The second part focuses on BIM and its capabilities. The sub- and background questions reflect the different parts of the research:

*What is the level of knowledge about critical materials in the building industry?*

*What strategies are available to mitigate critical material problems?*

*What are critical materials in the European Union?*

*What data of critical materials should be disclosed per phase of the life cycle?*

*What role can BIM play to facilitate knowledge and solutions for critical materials?*

*What is the role of material parameters in Building Information Modelling processes?*

*What steps can be taken to develop critical material data processing?*

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**Design assignment in which these result.**

The aim of this thesis is to facilitate knowledge of, and solutions for, critical materials in the built environment using Building Information Modelling. The first objective is to find relevant information for building components containing critical materials to optimize their lifetime. The second objective is to test Building Information Modelling as an approach and tool to process the relevant information within standardized datasets.

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**Background**

Over the last century, resource extraction has grown rapidly and is expected to increase even more due to growth in global population and economic development. Especially the environmental impact of the building industry is enormous, as it accounts for the use of 40% of the natural resources and the production of 45-65% of the waste disposed to landfills (Franzoni, 2011).

Another urgent problem we are facing currently is climate change. With increasing evidence of accelerated climate change, urgent actions need to be taken to reduce the carbon footprint. The building industry is a large contributor to CO2 emissions, with buildings responsible for 40% of the total energy consumption (Circulaire Bouweconomie, 2018). To reduce the carbon footprint, the building industry is responding with smart technologies; renewable energy and smart and efficient energy systems.

However, the risk of disruption in the supply of the resources needed for these high-tech industries and renewable energy technologies is high. Researchers and governments like the European Commission labeled them as critical materials. Critical materials can be described as materials which are highly important for our current economy, while their risk of disruption is high. The EU aspires to reduce the dependency on the import of critical materials.

When buildings become more energy efficient and their systems more advanced and complex, the demand for critical resources increases (Ruuska & Hakkinen, 2014). Critical materials are often present in extreme small quantities and provide unique performance characteristics (Peck, 2016). This makes them not easy to substitute and therefore indispensable to achieve sustainable development goals.
While critical materials are obviously highly important, there seem to be significant gaps in awareness and understanding of these materials. Critical materials are elements or combination of elements, which are part of materials. A building technologist or architect does not take this level of detail into account. However, better understanding of these materials could lead to more efficient use. Not only in an adaption of the design of the products containing these materials, but also in the use of these products.

A closure of material loops, better known as circular economy, is necessary to make more efficient use of these resources. Optimizing the design of products for longer lifetimes, facilitating predicted reuse and high intensive recycling can be part of possible solutions (Kohler, Bakker and Peck, 2010). Securing quality and material recovery of the building components needs to be integrated in a very early stage of the design process of a project (Geldermans & Jacobson, 2015). The decision of materials is made during the design phase and the design of the building product affects the potential of reusing or recycling of its components. This phase decides the length of the life of the product, which if shorter, speeds up the rate of the (critical) material consumption (Peck, 2016). Moreover, many critical materials still have very low recycling rates which increases the demand of virgin materials (EASAC, 2016), this makes it urgent to make components containing these materials reusable, instead of recyclable.

The life cycle of the design should be analyzed to optimize the use of materials and to give a better understanding of what is expected during its whole lifetime. The lifecycle of buildings extends from the extraction of raw materials, through the construction and use phases to demolition and eventually waste disposal, reuse or recycling of building components (Herczeg, Mckinnon & Milios, 2014). Life Cycle Analysis of buildings make new type of information necessary compared to a traditional building process. The abundance of needed information requires efficient information technologies.

To make the materials and their components reusable, resource information and data sharing is crucial. Information is required about the location and application of materials and for which future applications they could be used within the Urban Mine. The Urban Mine can be described as all materials stocked in products and buildings around us. According to Umicore (2012), the Urban Mine can be much richer than primary mining ores.

Data about the stocks and flows of critical materials is therefore considered as highly important to the European Commission and new possibilities need to be developed to link information to datasets of dynamic economic models. Datasets need to be standardized to easily compare and combine them. Currently product or building information is described in dissimilar datasets and data about the exact content of materials is generally missing. Information about the stocks and flows of materials via harmonized database systems can be an approach from material, product and waste perspective. To realize this, the content over the full value chain must become transparent (Tukker & de Koning, 2018).

Building Information Modelling (BIM) as a method to organize building processes, can take into account all data needed for the whole life cycle of a building by collecting information from all involved stakeholders. The model can be used during the whole lifetime of the building to make better informed decisions. Documenting all the relevant material data in the model, the model could function as an Urban Mine Platform; a platform wherein data is available on different flows of materials in buildings and products around us.

**Process**

**Method description**
LITERATURE RESEARCH
The first phase of this research analyses the basic principles of the three topics parallel; critical materials, the circular economy and Building Information Modelling.
An in-depth literature study has been conducted. This research mainly focusses on finding relevant data to optimize the lifetime of critical materials, which can be documented in a BIM model. Literature about critical materials and materials in general is consulted to find relevant information to extend their lifetime. Literature about the optimized material use is mainly focused on circularity. The last part of the literature review is about Building Information Modelling and standardized data. Herein, general literature about BIM as an approach and earlier research on material passports is consulted.

EMPIRICAL RESEARCH
Part of the research is discovering information technology programs to make better informed decisions on the material choice and to process the found data into Building Information Modelling. For material decision making CES Edupack is explored.
To gain experience in the use of Building Information Modelling, practical experiences within different BIM environments has been gathered to find data processing possibilities. The software Revit Autodesk (Windows) and ArchiCAD Graphisoft (Windows and iOS) are mainly used during this research. This thesis explores various methods of processing datasets within BIM.

CASE STUDY
The empirical part of this research is supported by a case study to understand the composition of a relevant building product and to process this data into BIM. A building component is chosen as a case study. During the analysis of this building component, relevant information about the composition has been identified and processed into a standardized dataset. This data is tested in different BIM environments; ArchiCAD, Revit, text formats and BIM viewers.

INTERVIEWS
The first interview has been developed for the industry and is linked to the case study. Before composing the interview questions, questionnaires and their outcomes have been analyzed on a similar topic. The reviewed interviews have the same objective; namely to identify the response and knowledge of the industry on critical materials. That way the outcomes could be compared with each other to find conceivable differences. Preliminary, a pilot interview has been conducted with a start-up company to test the relevancy of the questions and to get an insight on the knowledge within this industry.
The second interview is conducted after re-consideration since the industry did not seem willing to collaborate on this research. Experts concerning critical materials and circularity with different backgrounds are interviewed to get their perspective on critical materials in the built environment and their documentation. This part has been done in the end phase of this research and serves mainly as a validation.

FRAMEWORK
Based on the results a framework is elaborated step by step. In this framework relevant information about material choices, the application of materials for an optimized lifetime and the corresponding data is outlined.

Finally, conclusions and recommendations for further research are provided. The methodology is outlined in Figure 1.
Literature and general practical preference

Reference list in report.

Relevance
With all developments in the built environment at the moment, this study is highly relevant. With increasing fact of climate change and a thrive to reduce the carbon footprint, the built environment reacts with high-tech systems and renewable energy technologies to reach sustainable development goals. Critical materials are indispensable for the clean energy transition and the aim for energy efficient buildings.
The European Commission is looking for new possibilities to trace materials and receive more accurate information about the stocks and flows of the materials. Building Information Modelling is increasingly used in architecture, engineering and construction industry to provide a more efficient information flow among all stakeholders. Nowadays more and more companies are implementing BIM.

Time planning