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CIRCULAR DECONSTRUCTION HANDBOOK

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CONCEPT FOR REVIEW AND ADDITION

BLOCK MATERIALS BV
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BLOCK MATERIALS

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HOW SHOULD I READ THIS HANDBOOK?

A Handbook is being drawn up to support the implementation of various projects within European and Regional programs for Circular Building and Demolition, like Digital Deconstruction. Such a Handbook can be designed with the different user groups in mind.

Many of previously created documents, texts, plans, schemes and ideas fit into a handbook, but are now more accessible from the user's perspective of the property owner or project owner. A perspective that can later be expanded to other target groups, such as the architect, the construction company, the demolition company or the support for the various projects in the field of Circular Construction, Deconstruction and Demolition.

By taking the property owner as the basis for this Handbook, not only is the perspective of a project or case chosen, but all process components can also be linked to decision-making questions that a property owner has about how to deal with his or her buildings and the materials contained therein. In other words, the sum of all decision-making questions also provides an interpretation of the cost-benefit analysis that every real estate owner has to deal with on how to deal with the sustainable demolition of a building.

An important perspective, also for other user groups, because with Circular Construction and Demolition it is in fact the owner of a building who makes the final decision on how his or her property is handled. Incidentally, this does not only have to be a building, but can also relate to the materials that are present in a building or that are removed from a building. Which either belonged to the owner of the building, or have remained the property of a supplier of these materials.

Where it is relevant to bring forward the perspective of another user, as a derivative of issues for the owner, this will also be mentioned at the same time. Only these perspectives will then remain in specific versions of this Handbook for certain user groups. However, because this Handbook is about the perspective of the owner, many lines of Circular Construction and Demolition do come together at this level, and much less so for the other user groups that only cover part of the integral chain.

The current version of the manual is a version under construction. And is supplemented and updated quarterly. This 0.6. version reflects the structure of the manual, has been further fleshed out and interpreted, and has been updated from an earlier version with:
- the reports of the European Project Digital Deconstruction,
- several visits to projects,
- reports related to Circular Construction and Demolition in various European countries,
- insights from the European projects Demo-Blog and CircularB.

The process components in each chapter can be seen as the beginning of the script for any project owner. We will describe examples of projects and cases at the beginning of this handbook, because in the coming years Circular Construction and Demolition, and in particular with regard to the reuse of materials from the Built Environment, is particularly concerned with bridging the gap between the practical aspects of Circular Demolition and

Reuse of Materials on the one hand and various scientific and theoretical insights related to Circular Construction and Demolition on the other. A gap that is wide open, but for which attention is actually increasing, partly caused by sharply rising material and energy prices.

The Handbook will also serve as a guide to change, because Circular Demolition or Digital Deconstruction is about how things around the construction, use and disposal of buildings and materials can be changed. From a classic way of building and demolishing to a circular way of building and deconstruction. Where are the possibilities for behavioral change and who are the "stakeholders" where this is possible?

So far, the experiences in projects and cases show that the architect and the construction company are weak links in the change process, the property owner a strong link, but characterized by a lack of knowledge, and the owner of the materials is in fact the 'game changer'.

However, in everything the architectural or building consultant is the knowledge link between all parties and this person must be able to be trained, partly based on examples and projects in which the architectural or building consultant is responsible. Projects in which there is a continuous cost-benefit analysis because the industry and the entire chain of companies and organizations that work with building materials are cost-driven, and therefore often make decisions for a short term. Circular Construction and Demolition, however, is primarily value-driven. Values in terms of the physical side of a material, which must be able to be maintained, value in material terms, in the sense that a material must be able to fulfill the highest possible function in society, and value driven in terms of the environment, where the use of materials should not be at the expense of our living environment and nature.

This requires the need to make the value of materials transparent, and that this value must also be able to flow back to the owner. The architectural or building consultant must be able to make this analysis and prepare quotation requests to demolition/dismantling companies, planning and construction companies to provide services, whereby the materials remain with the original owner and are not taken by the demolition or construction company, other than against payment of the highest possible value of the materials in society. A big challenge.

Activities for which this Handbook will be of significant help!

Questions are open for answers at each chapter, as are comments on what is now worded in each chapter in the handbook. Scientific and project references are continuously added to the different versions.

Because the updated version of the manual is still based on the property owner's perspective, not all parts of the Digital Deconstruction project will be discussed equally. This applies to the Reversible BIM module, when it comes to supporting the architect and the demolition company.

These become clearer if we also extend the handbook from the user perspective of these groups. The full version of the handbook will cover all user perspectives, including all processes supported by the work on the DDC modules and other relevant parts of the project.

A handbook is a large document. If you are looking for specific parts, use the “Topic Guide,” which is included after this introduction.

Suggestions for improvement are therefore more than welcome!

Simon Duindam

Heerlen/Melbourne, October 15, 2022

CONTENT

TOPIC GUIDE

If you would like to quickly learn more about a specific part of the entire Circular Demolition chain, please use the subject guide below. For many subjects, the table below indicates which part, chapter or paragraph can be consulted for this subject. However, remember that true Circularity involves understanding the entire Demolition chain. But it often starts with a link.

Topic	Part	Chapter	Paragraph
3D scanning with mobile scanner	1	3	
Liability for delivery of materials from a building	1	4	
European Union Circular Economy Action Plan	0	2	
Waste as a raw material	1	1	9
Decision-making and finalizing a Cost-Benefit Analysis	1	7	
Blockchain Technology	1	3	
Securing materials during demolition	1	9	
Circular Construction23 (CB23)	1	3	9
Cirdax	1	3	
CO2 rights	1	5	
The cost of inventory	1	6	
Digital Materials Database	1	3	
Discount Rate Cost-Benefit Analysis	1	7	
Property rights for materials	1	4	
Embodied Co2	1	5	
Expertise and training in preparation	1	1	7
Reuse potential	1	3	
Recovery of materials	1	11	
How to organize the preparation future building	1	1	7
How to set up a Cost-Benefit Analysis	1	2	
ICE database	1	5	
Identity for materials	1	4	
Inventory of materials in a building	1	3	
Qualitative Cost-Benefit Analysis	1	2	
Lean philosophy	1	8	4
Releasability	1	3	
Social Materials Balance of a Building	1	5	
Social valuation of materials	1	5	
Social values in circularity	1	5	9
Marketplaces for secondary materials from a building	1	12	
Matching requester and supplier of materials	1	12	
Storage of materials	1	10	
Practical aspects inventory of materials	1	3	7
Practical aspects of the demolition preparation	1	8	2 and 7
Practical aspects of a Cost-Benefit Analysis	1	2	7
Practical and Process Activity Blockchain Registration	1	4	7
Practical and process activity Social value	1	5	7
Practical and Process Activities Cost-Benefit Analysis	1	7	7
Principles of Circular Economy in Construction	0	2	
Products-as-a-service	1	2	10
Reversible BIM	1	3	
State of affairs Circular Economy Construction	0	2	
Circularity forward contracts	1	4	
Track-and-Trace of materials (over time)	1	4	
Challenges of the Circular Economy for existing buildings	0	2	
Demolition execution	1	9	
upcycling	1	11	
Expectations of sustainable demolition results	1	1	7
Processing of materials	1	11	
Preparation activities for the future building	1	1	
Pre-demolition - preparing for demolition	1	8	

Part 0

Overall Vision, Challenges and Objectives From the Handbook For the Property Owner

1 INTRODUCTION HANDBOOK

The general vision behind the quality framework of the Handbook

The basis of the Handbook lies in the daily experiences of the real estate owner - pilot owner about the quality of the various demolition processes of his or her real estate. Quality is thus shaped by extracting from these daily experiences those experiences that are really shared with each other and considered 'good' or 'the best'. And can therefore also be used frequently in the daily work of the property owner, as a reference for a new demolition plan to be made or adapted.

Quality within the Handbook is therefore primarily not formed by standards for production, legal requirements, professional registrations, etc. Even if requirements from governments, suppliers, own organization, residents, and other stakeholders set preconditions that must be considered. These are the preconditions, but not the heart of the Circular Deconstruction Handbook.

The Handbook is the result of a user's working method, in which the following processes of the Property Owner - Pilot Owner are supported based on daily experiences and with the aid of various aid documents, tools, methods and techniques:

1. Preparation of all activities
2. Making a qualitative cost-benefit analysis of the demolition method of a building.
3. Inventorying the materials present in a building and registering these materials in a digital materials database.
4. Assigning rights to materials
5. The social value assessment of the reusable materials in a building.
6. An inventory of the costs of services related to the desired demolition of the building.
7. Completion of the qualitative and quantitative cost-benefit analysis and decision-making on the method of demolition of a building
8. Preparation for Demolition
9. Conducting the demolition and securing the value of the materials in the building
10. Securing the materials for physical reuse in a depot, including an overview of available materials for the architect and construction company.
11. Processing materials
12. Organizing the physical reuse by trading the materials on an internal or external marketplace.

The Handbook describes the details of the processes and the associated documents, experiences, questions, and answers for each part of the process. This also results for each process component in a template for the property owner – project owner, with which each process component can be completed. A script for every sustainable demolition project.

A fixed classification is used for each process part of the Handbook. Each section in the process provides content to a part of the process, or makes a connection with another process part, or indicates which sources have been used to color the content of the process part. The sections are the following:

1. Introduction: a brief description of this part of the process and the goal to be achieved in this part.
2. Input: a description of which tools or previous results of other process components are needed to further develop this component.
3. Products and services: A description of the products or services that can be realized with the elaboration of this part of the process.
4. Methods and Techniques, Templates, and Instruments: an elaboration or clarification of the tools (methods & techniques, templates, and instruments) that are used in this process part to realize the products and services.
5. Results: a description of the results that are achieved based on the products and services in this part of the process.
6. Quality factors: a description of the various aspects of quality that are discussed in this process part.
7. Process activities: description of the activities that are or have come up for discussion in this process.
8. Questions and answers: a description of all questions and answers for this part of the process.
9. Comments: a summary of the comments and experiences discussed in this part of the process, including any reflections.
10. References: an overview of the sources and (scientific) references used when describing this process component in the manual.

The Handbook thus also represents the collective memory of the partners of the Digital Deconstruction project. To use that collective memory to help everyone in their daily work, it is therefore important that experiences are shared. That these experiences are provided with insights, and that these insights can also be given back to all participants of a project via an electronic knowledge system, by participating in additional workshops for all members and by participating in learning circles. In this way, every participant also knows what is good, which could save a lot of puzzling and searching time in daily work.

1.1 PROJECTS AND CASES

A large amount of information has been collected for the handbook about projects and cases that are working with Circular Deconstruction. This concerns primary sources, which the Handbook team works directly with, and important secondary sources of projects in which experiences and examples are discussed that are important to share for the realization of a regional sector Circular Deconstruction.

As the primary sources we know the projects from:

a. Digital Deconstruction
b. Activities Handbook Circular Deconstruction in Parkstad Limburg

As the secondary sources we know the projects from:

c. Regional Innovation Hubs within Digital Deconstruction
d. Reports of European projects

We will briefly describe each project in the table below. In the reflections and references to each chapter in this handbook, we will then make a connection with the projects. In doing so, we show for each part which aspects of a project give substance to the necessary practical aspects of Circular Deconstruction for that part.

Primary projects							
Number	**Name**	**Owner**	**Sector**	**Sort of Building**	**Type**	**Location**	**Country**
1	Housing association homes	Vilogia	Home	16 homes	Demolition	Lomme	France
2	Gare Villeneuve Saint George	SNCF/AREP	station	Station building	renovation	Villeneuve Saint George	France
3	Hof ter Laken	Kempens Landschap	Monument	Castle	Demolition	Heist op den Berg	Belgium
4	School Berlaar	Kempens Landschap	Education	School building	Demolition	Berlaar	Belgium
5	Heerlen City Hall	Gemeente Heerlen	government	Office building	Demolition	Heerlen	The Netherlands
6	Thermae Museum	Gemeente Heerlen	Museums	Museum	renovation	Heerlen	The Netherlands
7	Ettelbrück Station	CFL	station	Station building	Demolition	Ettelbrück	Luxembourg
8	Promenade	Gemeente Heerlen	Public space	Square/Street	Renovation	Heerlen	The Netherlands
9	Brightlands Office	Brightlands Chemelot	Industry	Office building	New constru	Geleen	The Netherlands
10	Processing Plant	Renewi	Industry	Industrial complex	Processing	Eindhoven	The Netherlands
Secundary projects							
Number	**Naam**	**Owner**	**Sector**	**Sort of Building**	**Type**	**Location**	**Country**
1	Croix Luizet	Est Metropole Habitat	Home	100 housing units	Demolition	Villeurbanne, Lyon	France
2	1 Triton Square	British Land	Services	Office building	Renovation	London	Great Britain
3	80 Charlotte Street	Derwent	Mixed	Mixed construction	Refurbish	London	Great Britain
4	JLL Office Fit-out	JLL	Services	Office building	Renovation	Manchester	Great Britain
5	Roots in the Sky	Fabrix	Services	Office building	New constru	London	Great Britain
6	Holbein Gardens	Grosvenor	Services	Office building	Refurbish	London	Great Britain
7	The Forge	Landsec	Services	Office building	New constru	London	Great Britain
8	Blackrock Street	One Manchester	Home	Houses	New constru	Manchester	Great Britain
9	Het Enterprise Centre	University of East Anglia	Education	School building	New constru	Norwich	Great Britain
10	Cambridge Avenue	SEGRO	Logistics	Shed	Rebuild	Slough	Great Britain
11	The Entopia-gebouw	Cambridge Institute for Sustainability Leadership	Education	School building	Renovation	Cambridge	Great Britain
12	Timber Square	Landsec	Mixed	Office and Shop	Renovation	London	Great Britain
13	The Burrell Collection	Gemeente Glasgow	Museums	Museum	Renovation	Glasgow	Great Britain
14	Canal Reach	Bennett Associates	Services	Office building	New constru	London	Great Britain

2 CIRCULAR CONSTRUCTION AND DEMOLITION: AN OUTLINE OF THE SITUATION AT THE END OF 2022

2.1 WHAT IS A CIRCULAR ECONOMY?

The Ellen MacArthur Foundation defines circular economy as "A *system solutions framework that addresses global challenges such as climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design:*

1. *Eliminate waste and pollution,*
2. *Circulate products and materials (at their highest value) and*
3. *Regenerate nature.*

The world population is constantly growing and is confronted with new needs for new structures and buildings. This puts enormous pressure on our environment and resources. The construction sector is responsible for approximately 33% of greenhouse gas emissions, 40% of waste generation and 40% of material consumption (Hossain & Ng, 2018; Ness & Xing, 2017).

In 2020, the European Union adopted a new Circular Economy Action Plan (CEAP) with more concrete measures to reduce pressure on natural resources and create sustainable development. Circular Economy (CE) action plans involve progressively decoupling economic activity from consuming finite resources and designing a second life for waste. Circular models play a key role in this.

A circular model distinguishes between technical and biological cycles, where:

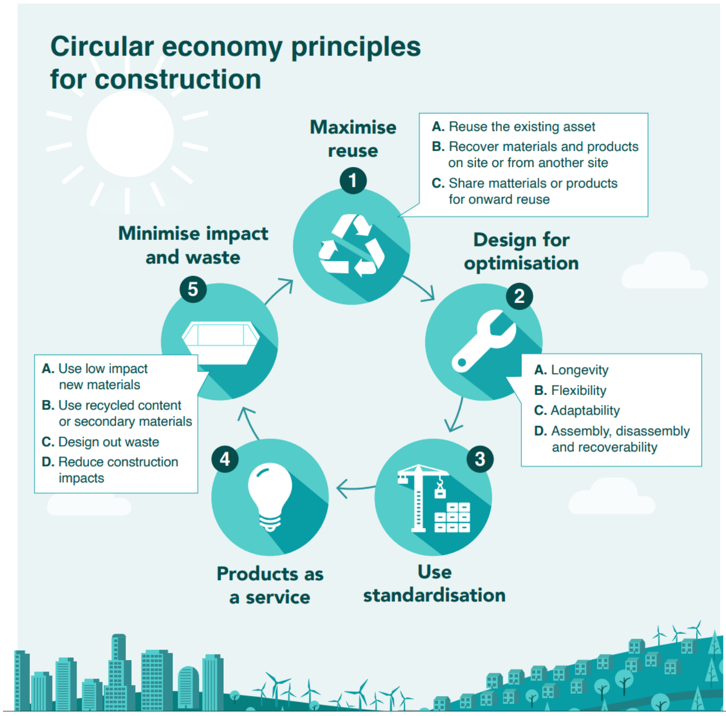
1. Biologically based materials and building components in general are designed to provide feedback to and regenerate living systems.
2. While engineering cycles recover and restore products, components, and materials through strategies such as reuse, repair, remanufacturing or (as a last resort) recycling.

The application of CE principles in real estate, building design and use (adaptability, sustainability, waste reduction and high-quality management according to the European Commission (EC, 2020)) is aimed at new construction where circularity can be embedded and facilitated from the early design phase and thus throughout the entire life cycle of a building and its components and materials.

Conversely, circularity in the context of existing buildings has not yet been defined (Kyrö, 2020). The multitude of definitions of CE, and more specifically circularity in the built environment, does not contribute to a cohesive, systematic approach. CE should be seen as a business strategy, not just waste management or a design strategy.

In response to this, various principles have been developed relating to Circular Deconstruction. The figure below, which is taken from the report, *Insights on how circular economy principles can impact carbon and value (August 2022),* from the UK Green Building Council, shows these five principles in more detail. The report, which was written primarily with a focus on reducing CO2, is also a practical guideline for preventing material loss during demolition and renovation due to the direct connection between reuse of materials and reducing CO2 by preventing new production of materials.

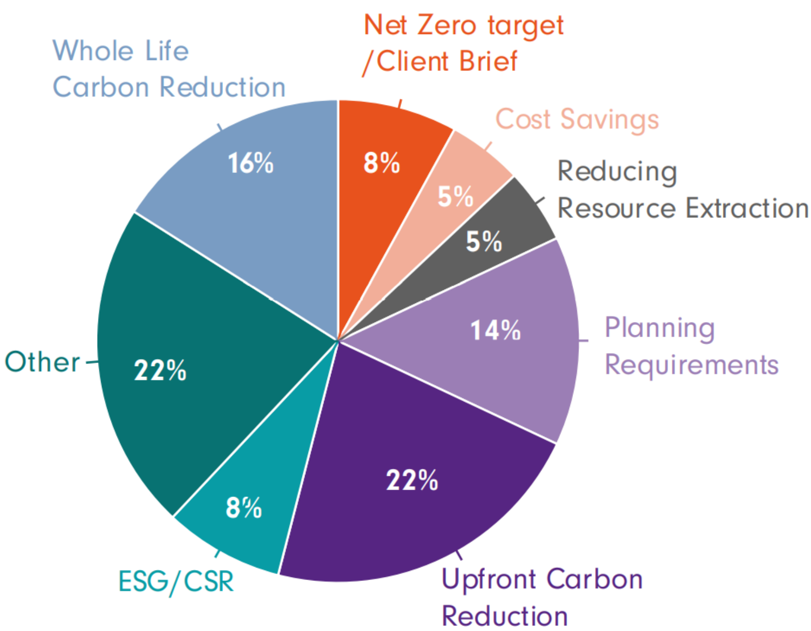
Figure 2: Circular Economy Design Principles



3.

Precisely because this Handbook contains various practical tools for Circular Deconstruction, it is good to consider these five principles. In the remainder of the Handbook, we will therefore also be able to refer to these five principles and, where possible, to the Key Drivers below for the use of Circularity in Buildings.

Figure 3: The Key drivers for using circularity on building projects



2.2. EXPLANATION OF THE FIVE PRINCIPLES

2.2.1 Principle 1: Maximize reuse

a. Re-use of the existing building: Re-use of an entire building, or re-use of a significant part of the existing building, to meet similar or diverse needs and/or uses (e.g., from industrial to mixed-use) while current regulations and standards are exceeded through restoration or major changes.

b. Reclaiming materials on-site or from another location: Incorporating reuse elements and materials recovered from the existing site or from another site in the new development.

c. Sharing materials or products for further reuse: Where materials and products cannot be reused on site, they are sent for further reuse through a broker or back to the material supplier for refurbishment, reuse, or recycling (as a last resort).

2.2.2. Principle 2: Design for Optimization

a. Design for longevity: Create a building with well-defined long-term needs, which is sustainable, resilient, and able to cope with societal and environmental changes. It requires little modification/no replacement of parts due to its 'loose fit', generous proportions and willingness for alternative technologies.

b. Design for flexibility: Balance the needs of the present with how those needs will change in the future. Enable change through frequent reconfiguration, including reconfiguration of non-structural parts - configurations are likely to be pre-agreed with planning and building management and will not involve 'wet transactions' or waste.

c. Design for optimal adaptability in a building: meeting the needs of the present but considering how those needs may change in the future, enabling change in the form of periodic remodeling.

d. Design for assembly, disassembly, and reparability: Products and services are designed to be partially assembled, deconstructed, and reused or recycled.

2.2.3. Principle 3: Use standardization

a. Designing and constructing buildings that adopt standardized elements or modular designs for materials and products that allow a reduction of construction waste and easier reuse in the next life. Standardization combined with off-site methods that reduce waste can reduce carbon upfront. But standardization in a design could increase carbon if not applied carefully and strategically. Standardization also has close ties to Designing for Deconstruction as the system is designed for easier reuse. There are also links to flexibility and adaptability if the standardized components are designed modularly and interchangeably, be it internal furnishing or structural components.

2.2.4. Principle 4: Products as a service

a. Promote and establish a payment structure that allows customers unlimited access to resources, but only pays for what is used, or for the outcome associated with their use. This means a transition from selling products to selling services. Products as a Service (PaaS) has the potential to reduce carbon and material usage through efficient maintenance and renovation cycles, as well as take-back programs that focus on eliminating waste and recovering or adapting products for future use.

2.2.5. Principle 5: Minimize impact and waste.
a. Use new low-impact materials: All new materials specified in the development are low-impact materials that have little or no adverse impact on the environment or human health over the entire life cycle.
b. Use recycled material or secondary materials: Recognize and encourage the use of recycled material and secondary additives, reducing the demand for virgin material and optimizing material efficiency in construction.
c. Waste design: to design waste over the entire life cycle of the building so that there is minimal waste during the design, construction, deconstruction, and next life of the built asset. While waste design is critical, it should be noted that when designing for future adaptability and flexibility, the structure may be over-specified to support additional loads in the future.
d. Reduce construction impact: Ensure construction sites reduce waste on site, including packaging.
e. Gentle impact materials identified in the case studies did not lead to higher initial carbon emissions. However, the full LCA of gentle impact materials should be considered to ensure there are no unintended carbon impacts due to frequent replacement or refurbishment cycles. Using gentle impact materials can result in buildings having a lower LCA than renovating the existing building.

2.2.3. Challenges for the Circular Economy in existing buildings.
Existing frameworks to implement and assess circularity suffer from a mismatch between supply and demand. There is an oversupply of theoretical guidelines and tools that illustrate the basic principles of CE in buildings. Yet most tools serve the same purpose, while there is a need for practical evidence on the usefulness of these tools and their impact on the design process to highlight best practices.

With very few examples of implementing CE in practice, the practical transformation from a linear business model to a circular model for Building and Demolition is still the most important (research) gap in terms of consolidated circular practices driving all companies and organizations towards improving the circularity of their products or services and encouraging subsidizing policies.
Outlined below are some of the challenges related to the above gap, which we are trying to reduce with the content and guidelines of the handbook.

a. To take full advantage of the implementation of circular strategies, supply chain management and monitoring must be essential. This includes ensuring an efficient flow of information between stakeholders (Cambier et al., 2020). In this regard, the need for matchmaking tools to connect verified stakeholders is emerging. A smooth process also requires legal support and guiding policies to ensure compliance with circular strategies.

b. The application of circularity strategies in the construction and construction and real estate sectors is still hampered by the lack of innovative business models that ensure implementation without jeopardizing economic viability and value determination by market players.

c. Reclaimed materials from existing buildings face a critical barrier in their technical compatibility and quality assessment, which casts doubt on their direct reuse. This leads to downcycling processes, attracting additional resources and energy flows.

d. Various tools have been developed for the Circular Deconstruction to support decision-making about designing and/or assessing buildings for circularity. Most tools have been developed to focus on specific aspects of circularity without considering other aspects, such as supporting products and material choice by substantiating only material-related indicators based on their environmental impacts.

e. However, the available tools fail to address a comprehensive circularity conception and lead to a loss of critical power when used individually as they fail to assess all other key design aspects e.g., build composition and connectivity between elements, durability, and longevity of building components. This is because circularity values arise when specified intrinsic properties (material and product properties) intersect with relational properties (building design and use properties) (Geldermans, 2016). For example, a building can be made of 100% circular materials and products, but when these are inaccessible for replacement or maintenance, the building system becomes non-circular.

f. More recent tools have been developed in the CE spectrum, such as Circular Building Assessment Prototype (CBA) developed by the European Union (EU) BAMB project, Circularity Calculator (IDEAL&CO, 2021) and Building Circularity Index (Alba Concepts, 2021). These tools introduce rating systems to calculate a circularity score with the aim of objectifying the circularity performance of a building or a building element. However, they are criticized for their lack of participatory and direct approach, which is fundamental to the need to assess the impact of assessment tools on the design process. In addition, there is no clear link between the outcome of these tools and the actual environmental impact of the investigated solution.

g. The challenges in identifying effects of actions in the circular economy:
   1. Circular design principles are rarely applied in silos.
   2. Circularity and non-financial values are not measured consistently.
   3. Inconsistent carbon assessments in a life cycle assessment.
   4. Carbon Assessments (life cycle) are not yet the norm.

h. An integrated, interdisciplinary, and transdisciplinary approach to CE implementation and assessment in the construction and real estate sector is needed for Circular Construction and Demolition. This can be achieved by ensuring that circularity is implemented in all related activities and management of the value chain, while reconciling its integration with other factors in sustainability frameworks. Until now, the implementation of CE principles in the design and management of buildings has been limited to the application of individual strategies related to certain aspects of circularity, for example the development of circular materials.

i. However, a circular construction approach is not limited to material circularity. It transcends individual aspects of the dynamic totality of all processes that enable a circular flow of these materials and products, including planning, management, design, operation, maintenance, and end-of-life aspects. Considering all value chain factors and policies that support implementation and economic value creation.

The new EU COST program CircularB proposes to create, assess, and benchmark a holistic framework for circularity in buildings, considering all phases of the life cycle, from planning to end-of-life options with all associated inputs. output streams of materials, as well as the involvement of a diverse group of stakeholders with interlocking specialties.

Within this context, the CircularB COST action will attempt to answer the following research questions:
1. How can circularity be defined as a complex property in buildings?
2. How can the principles of circularity be integrated into all phases of a building's life cycle, from concept to end-of-life, considering all components, products, and systems already during the design of new buildings and major renovation projects?
3. What are the drivers and barriers for the integration of circularity strategies in buildings for COST countries and beyond at the various levels? Have best practices been established?
4. Since existing circularity indicators and assessment frameworks are not sufficient to provide an integrated approach to the implementation of circularity in buildings, what are the other complementary aspects that are still missing, considering all technical, technological, economic, environmental, legal, and social factors? How can they be brought together in one inclusive model? Is there a possibility to express circularity as a complex characteristic in one indicator or index or is there a need for a set of indicators?
5. Is it possible to quantify a building's circularity potential, considering emerging possibilities for disassembly, adaptability, deconstruction, reuse, and sustainability, among other things?
6. Does circularity contribute to sustainability? What is the relationship between sustainability as an overarching goal and circularity as a sub-strategy to support more sustainable development?
7. How to assess the benefits and sustainability of circularity measures? Are there any compromises?
8. How can the stakeholders within the quadruple helix contribute to the realization of circular construction? What is their respective role in realizing a circular value chain? And what incentives are needed to make their roles more efficient?
9. What strategies and tools need to be developed to enable transformation along the entire value chain?
10. Are there additional design and development requirements for new (next generation) products?
11. How will circularity contribute to the availability of secondary materials?
12. What new business models are there – from leasing systems to take-back options?

Where possible, we will reference in the Handbook to the questions raised by the holistic, integrated approach advocated in the CircularB program.

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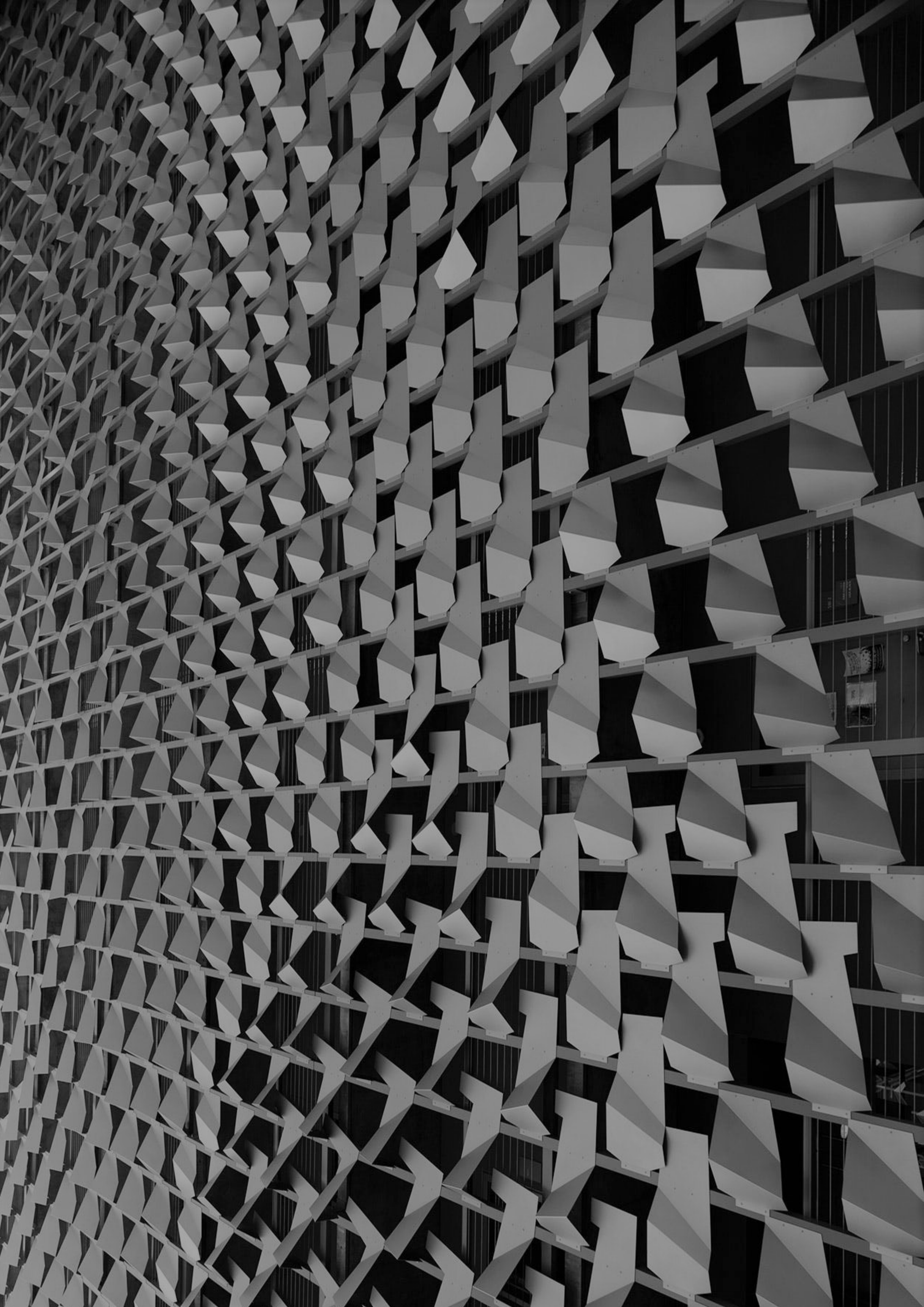


Part 1

The Real Estate Owner

Project Owner

1 PREPARATION OF ALL ACTIVITIES

INTRODUCTION

In order to make a good analysis of the future of a building and to reuse the materials present in the building in a high-quality way, this handbook provides structured access to a large number of tools that can be used in different steps. In order to use these instruments, as well as methods and techniques correctly, the user of the Handbook must have a good overview. For this it is desirable that all activities related to the reuse of materials in a building are properly prepared. This is also because of the wish to work as holistically as possible.

This chapter indicates which preparatory activities are desirable. The description of these activities also discusses the scope and quality of these preparatory activities.

1.2. INPUT

The following elements can be mentioned as input for a good preparation:

- Access to this handbook

- Access to 3D scanning expertise

- Access to releasability/RBIM expertise

- Access to the Digital Materials Database Cirdax (integrated with marketplaces and marketplace tools)

- Access to templates for a (social) cost-benefit analysis

- Access to drawings and other information resources related to a building

- Access to enough space on computer servers

- Access to general expertise/process control related to performing a reusability analysis of materials and the demolition and/or dismantling of a building.

- Access to a list of possible customers of the materials.

1.3. PRODUCTS AND SERVICES

No specific products and services are used in this part of the process, other than the services of a quartermaster/projectmanager for a project.

1.4. METHODS, TECHNIQUES, TEMPLATES AND TOOLS

- Methods and templates for setting up a project. It is desirable to have a form or application that indicates whether all parts of a preparation are actually present.

- Template Plan of Approach Circular Deconstruction Projects

- Template Project Plan Circular Deconstruction Projects

1.5. RESULTS

The result of all the preparatory work is the availability of the capabilities and expertise in inventory, project management, cost-benefit analysis and access to the tools to set up a process for reusing materials.

1.6. QUALITY

The expertise hired must provide the capacity and knowledge to carry out a project related to the reuse of materials in a building. If necessary, a project leader or consultant will have to be trained in the use of tools, tools and templates. A project leader must be able to carry out the activities mentioned in the Handbook in relation to a specific project. He or she will also have to be able to operate all the tools mentioned, or to manage and understand the expertise hired. The final competence test of the relevant project leader is the first delivery of an analysis on the reuse of the materials, as well as the actual delivery of the reusable materials to a depot, existing customer or to a new customer.

1.7. PROCESS ACTIVITIES

Examples of process activities in the preparation phase are:

A. About information and research

• Find and consult sources that collect information (eg in France: materiauxremploi.com, BAZED, Circolab, etc.)

• Search and consult authorized guidance documents (eg in France: REPAR, Guides FBE, Circolab, etc.)

• Provide extra time for studies (general).

• Be precise in the terminology used in the documents. Adding a glossary to the tender is an example of this.

• Use guidelines or existing specifications and templates for a draft tender (eg in France: document Circolab, etc)

• Provide access to as much existing information about the building as possible.

• Investigate different typologies of actors: potential building owners interested in reuse for their projects, specialized deconstruction demolition companies, social companies that propose specific works (preliminary recovery of products, stock, treatment, commercialization, reuse), associations, experimental designers , industrial and construction companies that can integrate reused/recycled materials, physical and online marketplaces.

B. About expertise and training

• Identify and contact a building owner and/or architect and/or design firm, ideally in the project's territory, who has experience with reuse approaches. They can provide you with targeted contacts from stakeholders, sources of information, tips and experiences.

• Organize or receive a special training session. Specialized actors propose training sessions based on experience and accepted methodologies for reuse approaches (for example in France: Bellastock, IDRE, Nobatek/Inef4, etc.)

• Make employees aware of the project in terms of context / vocabulary / needs for deconstruction and reuse approach.

• Ensure an exchange with local partners, who have already carried out circular projects.

• Make sure that all stakeholders understand each other, speak the same language and that the program is really understood. You can also suggest a glossary for all employees to use.

• Identify the existence of local parties that are able to deconstruct elements, support the project, store, treat and reuse materials. It can influence the feasibility of the wishes of a property owner, especially if there is a guaranteed purchase of materials that are released from a building and will therefore also be reused at a relatively high value.

• If you do not have the competences internally, find an experienced agency to approach the project and integrate as early as possible. Ideally, this support agency should be local to know the local context well.

• Find an experienced deconstruction and reuse control agency. Integrate them into the process as early as possible. Again, this means that time is set up/gained, which can be beneficial later on. For example, for a correct matching between supplier and requester of materials.

• Provide access to as much existing information about the building (drawings, design documents) to the support office

• Discuss these issues with the support office or project management team as early as possible:

- Is there a local site to store the deconstructed elements before they are sold, reused or upcycled?
- If reuse on the same site, does the control agency have a specific reuse mission?

• In certain cases, the building owner has minimal internal knowledge. However, if project management teams (architects + design offices) with expertise in Deconstruction and Reuse exist, a support office should not be necessary.

C. About facilities and processes

• Find a storage facility near the building being demolished.

• Internally, or with a support office, identify the resources/products that are commonly reused to understand the business model.

• Integrate preparatory deconstruction activities in the follow-up process. Take photos, keep traceability documents.

• Be sure of the safety of the interventions (access, deconstruction)

D. About expectations

• Be realistic, generally don't think about reusing all components of the existing building, but define general expectations and goals. This also includes the possibility of upcycling, because this prevents losses of materials, and may achieve higher economic values than with reuse alone. Upcycling can better match the current demand for materials.

• Determine whether you want/need to reuse the products in situ (during renovation or conversion). Decide with the owner if a few elements need to be deconstructed for his own needs on other projects

• Clearly express the wishes for deconstruction and reuse and define this as a crucial objective for the project.

• Frame the mission/expectations for the support office. Is it just an evaluator and stimulator of the project management team, or should it support the design team in designing and implementing the approach?

• Be clear in the tender about the deconstruction and reuse objectives of the project.

e. About reuse and sale of reusable materials

• Identify potential users / purchasers of the products, physical and digital marketplaces by searching the Internet (directly or through a website that collects information such as http://materiauxreemploi.com/, FCRBE, etc.), or by requesting information from local actors.

• With regard to potential users, you can also contact building owners or housing associations directly instead of a marketplace. Find information on local building projects, contact local councils, social housing owners, identified support offices and architects.

• Communicate on the Internet, local events and press, mainly to attract potential parties.

• Organize site visits if possible and have a person available to organize specific visits for interested parties.

1.8. QUESTIONS AND ANSWERS

The following questions and answers can be added to this chapter.

Question: Deconstruction takes longer than demolition and certain materials may not be immediately available. This is likely to increase development costs as well as reduce rental income in the short term.
Answer: Develop a detailed program and life cycle cost analysis and involve contractors early in the process to minimize the risk of delays. In the Entopia Building, contractors were engaged from the end of RIBA Stage 3 under a pre-construction service agreement.

Question: When products and materials are made for sale, rather than customer property, no optimization for future scenarios is usually undertaken.
Answer: Customer teams and designers should be encouraged to think about the future use of assets and one way to do this could be to include annual CO2 reporting in addition to LCA assessments. Take advantage of the marketing opportunities of future benefits, including buildings as material banks, such as the BAMB2020 project.

Question: The taste of the market is likely to change, and many buildings are not used for their full design life.
Answer: Longevity should not be used as a standalone solution, but instead be combined with deconstruction, flexibility, and adaptability. Better community involvement is needed to prioritize existing buildings first and how they can be used for another use, and where possible involve the end user in decisions to better design for future possibilities.

Question: The start-up costs for the 'tooling' of on-site production facilities if customers use their own standardized systems.
Answer: This should reduce initial costs as a customer's economies of scale develop. Off-site production facilities, if customers can ensure carbon and material savings through the standardized methods, will outweigh transportation carbon. On-site facilities can also speed up construction time, increase local employment and reduce transportation/construction intensity over time.

1.9. COMMENTS

The following comments can be added to this chapter.

1. The desired cycle of circular use of materials currently only exists for a few materials, such as metals. There is no cycle for the other materials, because after the materials have been used in a building, most of the materials after demolition (no disassembly) are landfilled, incinerated, or recycled in low quality. It is economically cheaper for these materials to buy new materials than to have existing materials undergo the operations of the cycle. However, for more materials, this balance is beginning to shift, fueled by price increases for new materials, as well as pricing the social costs of destroying existing materials. This is supported by liability arrangements and Co2 prices to produce alternative new materials (ETS rights).

2. Examples of waste processors of building materials show that waste is increasingly becoming a raw material, because after sorting and cleaning the materials, new raw materials are created that are competitive with primary raw materials. Same for products. Not because these secondary raw materials have really become cheaper, but because the costs of primary raw materials are rising explosively. This creates a business model for the cycle of secondary materials along the way of upcycling, whereby inventories of the costs and benefits of actions in this cycle model are significant to give as many stakeholders as possible an integral insight into their own derived revenue model, which often comprises part of the entire cycle. This in comparison with a classic way of building and demolishing, in which the disappearance of materials is an issue.

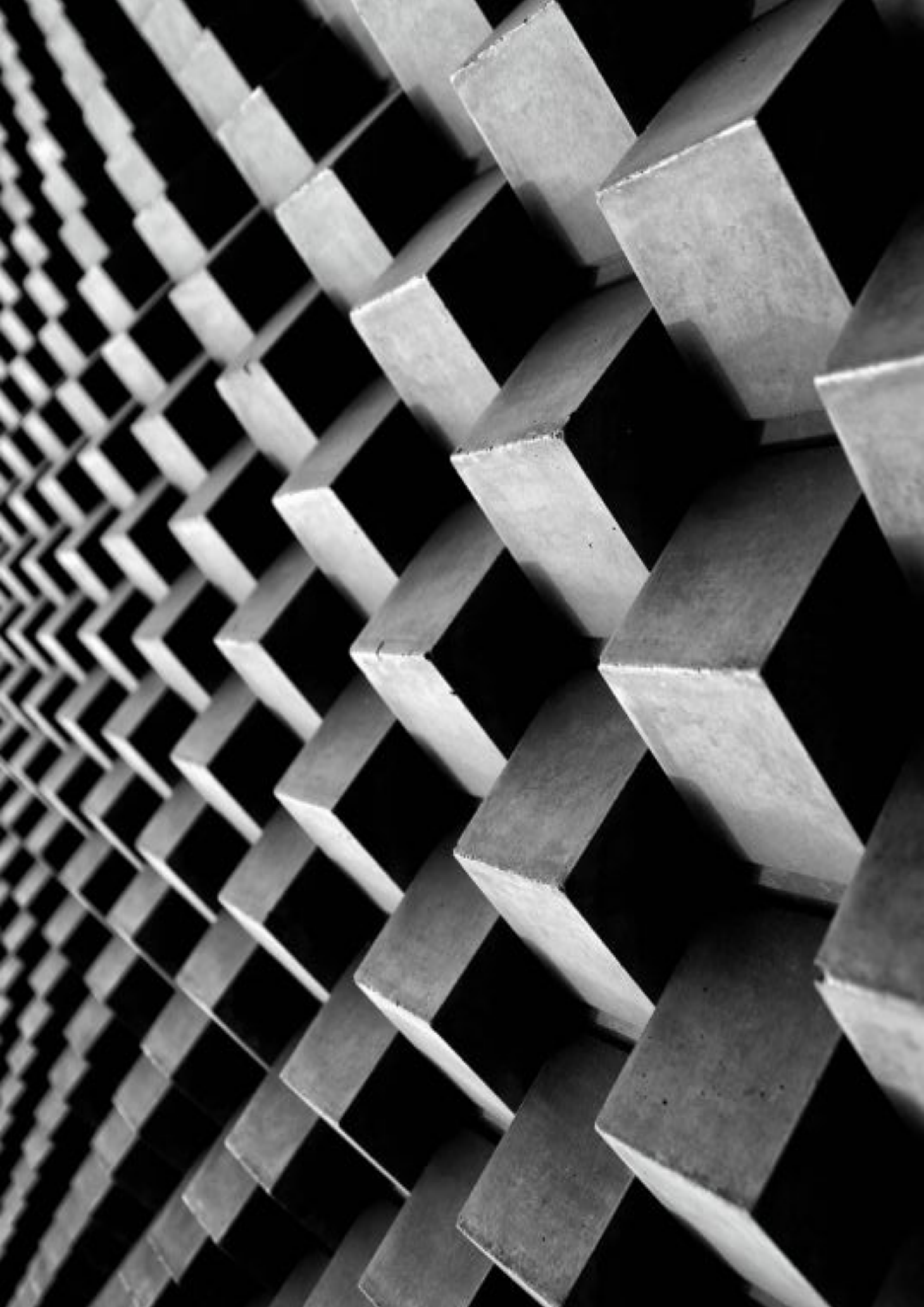
3. The following challenges related to Circular Construction and Demolition from the CircularB program are related to this chapter of the handbook:

• How can the principles of circularity be integrated into all phases of a building's life cycle, from concept to end-of-life, considering all components, products, and systems already during the design of new buildings and major renovation projects?

• How can the stakeholders within the quadruple helix contribute to the realization of circular construction? What is their respective role in realizing a circular value chain? And what incentives are needed to make their roles more efficient?

1.10 REFERENCES

No references have yet been added to this chapter.



2 MAKING A QUALITATIVE COST-BENEFIT ANALYSIS

2.1. INTRODUCTION

In his 1937 article "The Theory of the Firm", Ronald Coase called on everyone to examine a firm's transaction costs in its relationships with customers, suppliers, staff, and organization in comparison to the costs of individual contracts that everyone can share with each other, for every transaction one makes. For example, for every hour of work instead of an employment contract for a longer period, etc. And to tackle this case by case.

The comparison between classic demolition and circular demolition evokes a similar thought. Let us compare all (transaction) costs of both alternatives and compare them per pilot or case. So that, based on an analysis of these differences, it can also be found out what causes these differences and with which investments, forms of regulation, the various costs and benefits can be represented in such a way that Circular Deconstruction clearly has added value.

The pilots within the European project Digital Deconstruction provide the basis for this, as the various figures on costs and benefits can also be made transparent for each part of the circular demolition process. Every decision by an owner of a real estate object to do something with this real estate object is based on an analysis of the existing and desired situation with the real estate object. This also applies to demolishing the real estate object or extending the life of a real estate object. The analysis of what to do with a real estate object lists the various considerations, whereby an overview is made of the various costs and the diverse benefits. These costs and benefits can be expressed in both social and financial terms.

In this chapter of the Handbook, the distinct types and benefits are first listed, after which these costs and benefits are also provided with a quantitative value. The experience surrounding the demolition and reuse of materials in buildings shows that many decisions regarding the alternative use of a real estate object are made based on incomplete and asymmetric information. Moreover, the economic and therefore also the physical value of materials is currently insufficiently secured, because of which diverse benefits are underestimated and value-driven approaches are insufficiently used.

This chapter therefore aims to list the diverse types of information that provide insight into both the costs and benefits of the alternative use of a real estate object, as a source for reusable materials. In the subsequent chapters, the various qualitative elements of a cost-benefit analysis are then provided with quantitative data.

2.2. Input

To organize a qualitative cost-benefit analysis, the following input variables are needed:
a. An overview of the available materials in a building
b. An overview of the alternative applicability of these materials
c. An overview of the economic value of materials that can be reused
d. An overview of the social benefits of reusing materials
e. An overview of other income associated with the demolition of a building
f. An overview of the costs of inventory, transparency, and alternative use of materials in a building
g. An overview of the costs of removing materials from a building
h. An overview of the costs of making the quality of materials in a building or the removed materials transparent.
i. An overview of the costs of storage and processing. This also includes those costs that are necessary to restore the quality of secondary materials in such a way that they can be seen as a full replacement for new materials. And thus, can also be taken off without any problems.
j. An overview of the time of a project, so that information about materials is available in a timely manner for the matching process of supply and demand with specific customers.

2.3. Products and Services

A qualitative cost-benefit analysis leads to an overview of the different costs associated with the analysis of the alternative use of a real estate object and the different and related benefits. In addition, a qualitative cost-benefit analysis leads to insights into the benefits of certain materials if the materials are of good quality and can also be matched with buyers of these materials.

2.4. Techniques, Templates and Tools

The following templates and tools can be used to make a qualitative cost-benefit analysis:

- Excel form with cost variables
- Excel form with revenue variables

A Materials Database, such as Cirdax, can be seen as a support system for making cost-benefit analyzes for reuse of materials, because it must be able to store all information about these analyses, or by providing statistical data resulting from previous inventories and analyses. The latter functionality can only be applied if there is sufficient data on such stocks. Until this goal is achieved, the materials database gives us data about the materials in a building, which can be used as a semi-finished product in the cost-benefit analysis. Another semi-finished product is a clear methodology for the calculations behind a cost-benefit analysis.

2.5. RESULTS

The activities leading to a qualitative cost-benefit analysis led to the following results:

1. Overview of all costs that can be discussed in a cost-benefit analysis.
2. Overview of all benefits that can be discussed in a cost-benefit analysis.
3. The way in which the factors of time and quality should be dealt with in a cost-benefit analysis.

2.6. QUALITY FACTORS

The following quality factors are discussed in a qualitative cost-benefit analysis:

a. The existing quality of materials present in a building, as part of its identity.
b. The extent to which the removability of materials hinders or promotes the quality of the materials.
c. The extent to which an owner of materials can be held liable for the quality of the materials.

2.7. PROCESS ACTIVITIES

When preparing a cost-benefit analysis, the following process activities are discussed:

- Analyzing the costs associated with removing materials in a building.
- Analyzing which (alternative) benefits are associated with the reuse of materials
    a. Consider prices that are relevant to your own area. Prices may differ for an urban area (ex Paris) and for a regional place.
    b. Consider the available time to achieve a good match between supply and demand. The longer the period that information about materials is available before demolition is conducted, the better the (alternative) yields/benefits will be.
- Analyzing which (alternative) benefits are associated with the reuse of materials from a building.
    a. Estimation of product prices. For reuse of products, search marketplaces (online and physical), contact experienced parties, and for new products, search common databases (used for all construction projects)
    b. Contact interested parties to estimate whether products can be sold (not just offered), and if so, at what price? And when they need it, or if they always want to be a customer (depending on the market, conditions for reintegration, required treatment, etc.)
    c. Define a price (penalty) in case a buyer has reserved a product but refuses to accept that product, after the product has been disassembled.
    d. Analyzing other returns associated with the demolition of a building.
- Analyzing those information aspects that increase the transparency of the quality of materials.

- Analyzing the combined legal, economic, and technological aspects that ensure that reuse of materials is secured over time.
    a. Organize liability issues in the supply contracts based on the blockchain registration (tokens), when finalizing the inventory data in the Digital Materials Database (Cirdax)
- Analyzing, maintaining, and improving methodologies for making cost-benefit analyzes about the reuse of materials in a building.
- Calculating processing or repair costs for a primary quality. In this way, the alternative new price of materials can always be used for the revenue side of secondary materials. The costs of processing and repair are then added to the costs side of the calculations.

2.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Every question has an answer.

Is the possession and use of materials at your organization or your clients seen as a separate core activity or is this a side issue?
Respondent 1: This is a key point as we are now thinking about the importance of material reuse to save CO2.
Respondent 2: Not part of our activity (engineering firm). Separate core business for some of our customers who are not interested in reusing materials for their own needs and who are not reseller. Side issue for other customers: want to collect materials for their own needs
Respondent 3: Since our main activity is the restoration of buildings, more attention is being paid to the reuse of materials that must be removed. This is now a sideline.
Respondent 4: This will become a core problem as the municipality moves towards a higher circularity ambition.
Respondent 5: It is not our core business, but reuse is a goal that is laid down in the company's strategic plan.

Who owns your materials from a building after demolition? You, your client, or the demolition company that performed its services?
Respondent 1: Dependent on contracts
Respondent 2: In most projects this is the demolition company. Very rarely the owner of the building (only when a specific material has been identified for reuse)
Respondent 3: Usually the materials become the property of the contractor. Until recently, this was also included in most tender specifications
Respondent 4: Dependent on contracts
Respondent 5: French law states that a building owner is responsible for his materials until they are removed. In the case of reuse, a contract of assignment must be signed to change the property if the building owner does not reuse the material.

Question: Concerns about the additional program time and resources required because of the additional planning required for things like developing the lease of materials, working with PaaS providers, and spending more time with the tenant so they understand the lease requirements.
Answer: Calculate the cost savings from avoiding replacement purchases under a PaaS model.

Question: Tenants not caring for products, leading to higher maintenance and repair costs for the owner.
Answer: Under green leases, include a protection/maintenance requirement for items to ensure they are not replaced too often and are managed with care.

2.9. COMMENTARY

The following comments can be added to this chapter.

1. Interviews with demolition companies show that for them the ownership issue of materials is subject to change. Where originally there was often an implicit transfer of ownership of materials during the demolition or dismantling of a building, awareness is growing that materials primarily belong to the owner. The price of the services of the demolition or dismantling company strongly depends on the value of the materials that are "harvested" during the demolition or dismantling, so it is also important to know in advance what the exact value of the materials is. Both for the property owner, the demolition or dismantling company, or the buyer of the materials. The situation in France, where a legal document is required for the transfer of materials, will be discussed in several places in the future. Especially because materials are becoming increasingly valuable.
2. Interviews with a demolition company also show that the value of materials is strongly related to the issue of matching these materials with a customer. Reuse or upcycling of materials is therefore not only about preventing incineration or dumping materials, but also about the quality of the matching process between supplier and requester of materials. Two aspects play a decisive role in this: a. insight into the quality of the materials, b. enough time to complete the matching. Inventory of materials at the front of the demolition or dismantling process provides insight into the quality of the materials and ensures that more time can be set aside for matching these materials with the right customer. Or that all customers already have their containers ready at the building that will be demolished or dismantled. Both quality and time are examples of information issues, which are central to the valuation of materials. Whether these are parts of cars, as described in The Theory of Lemons by Akerlof (1970), or materials in a building.
3. Capturing property rights strengthens the quality and time/matching process, because property rights can also be used to organize forward contracts, liability of delivery and combinations with other property rights. Materials therefore no longer always must be in the possession of the owner of the building but can also remain with the supplier. In this way, the materials become part of a so-called Product-as-a-Service (Easter). The costs of establishing these property rights thus pay for themselves within guaranteed futures contracts.

2.10. REFERENCES

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References within projects

1. Luxembourg

Construction and demolition waste represents between 25 and 30% of the total waste volume in the European Union, making it the largest waste stream. The same situation can be found in Luxembourg, where efforts are being made to make the most of the potential of construction and demolition waste, and to collect demolition materials.

Luxembourg law requires that the prevention, reuse and recycling of construction and demolition waste be promoted in accordance with the waste hierarchy. The most careful sorting and removal of the various categories of waste must be done on the construction site to achieve a qualitative recovery. If this sorting cannot be done on site, it must be done after the collection of mixed waste.

The legislation also stipulates that when a building is dismantled, an inventory of building materials must be drawn up and submitted to the Environmental Service (AEV) upon simple request. This inventory is a valuable resource management planning tool, provided the information is updated during decommissioning. The main objective is therefore to promote the separate collection of building materials and their efficient use as resources in Luxembourg.

The Luxembourg Institute of Science and Technology (LIST), in collaboration with AEV, has developed a materials inventory model and an accompanying guide to help those involved in the planning, execution and documentation of decommissioning works to prepare an inventory of the materials and types of waste present, to be able to meet their legal obligations as efficiently as possible.

This inventory model is designed to help project owners - who as commissioners of the decommissioning works - take full responsibility for the planning and preparation of such an inventory. In practice, however, project owners have so far faced a certain lack about:

- Information about the materials to be included in the inventory and
- Concrete recommendations for a systematic approach
- Experience in such a process of planning and execution of a construction site

It was decided to develop inventory tools to clarify and facilitate compliance with applicable regulations. This is in view of the objectives of the revision of the European Waste Directive published in 2018 (Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste).

2. Shortened program times on UK projects

Most studies that use reuse of the building and the materials in the building saw or expect a reduced program time. While safety and deconstruction may require a longer demolition process, a sizable portion of the existing building will be on site once this process has been completed and the overall program will therefore be shorter.

While not solely attributed to the use of circular principles, 80 Charlotte Street, and 1 Triton Square both saw significantly faster rental times. For 1. Triton Square with the fastest pre-letting in London's West End in over 20 years.

3. Examples of Product as a Service

Products as a Service (PaaS) has the potential to reduce carbon and material waste through efficient maintenance and refurbishment cycles, as well as take-back programs aimed at preventing waste and recovering or adapting products for future use. The WLC (whole lifecycle costs) of PaaS should be considered before installation as there is currently limited evidence that products as a service lead to reduced carbon over the lifetime and no case studies incorporating PaaS have been provided. The case studies in the British Green Building report are taken from the websites of several PaaS companies, not all of which operate in the UK.

- eLight: Lighting as a Service (LaaS), eLight performs the maintenance of the lighting fixtures and installs an energy metering system to improve energy consumption efficiency. In one school they saved 62 tCO_2 e per year with the predicted annual savings from using eLight. At the end of their life, the original lighting fixtures are taken back by eLight and recycled and reused through Recycling Lives.
- Signify: By Lighting as a service, they offer a 50% longer lifespan, which indicates a CO_2 saving of the product.

3. Inventory and registration of materials

3.1. Introduction

In this chapter we describe the processes involved in the inventory of the various components and materials in a real estate object. We distinguish between different forms of inventory, as they can be done manually or with the help of scanners.

When making an inventory of the varied materials in a building, the different data about these materials can be recorded in a point cloud, (R)BIM system or a digital materials database. Various forms of metadata are used for this.

Inventorying has a threefold identity in the Digital Deconstruction project. The first step is to make a digital scan of the building using a scanner. The information collected by the 3D scan can then be imported into BIM software, which is the starting point for an RBIM analysis or Reversible BIM analysis to understand which parts of the building are eligible for deconstruction, i.e., the removing the materials from the buildings for reuse in a socially profitable way. The second step looks at the removability of materials in a building. The third step is the additional manual inventory of the materials not yet identified in the previous steps. Information stored in a digital materials database.

All three activities involve work and therefore costs, which we should be aware of. We also look at these activities in the form of services derived from each other. This means that the digital scan of the building provides the preconditions for the detachability analysis and the materials inventory. And the releasability analysis defines the possible depth of the material inventory. We also need to consider how these forms of inventory can be easily organized and multiplied, so that several people and organizations can perform these tasks and those involved in this process are not hindered by capacity constraints.

In this chapter we will distinguish, where applicable, between the three inventory steps just mentioned. Otherwise, the techniques and activities will be merged.

3.2. Input

- For the inventory of materials in a building, use can be made of a manual inventory through the deployment of a qualified employee in the field of making a materials inventory or an automated inventory using a 3D scanner performed by a qualified collaborator.
- A specialized RBIM expert can be deployed to inventory the removability of materials in a building
- A digital materials database can be used to register the various data arising from an inventory. The same goes for a BIM system, as well as a server with database to store the point cloud information and panoramic photos that emerge from 3D scanning.
- A special form of registration and metadata is the blockchain registration of the properties of materials in a digital materials database. This is aimed at recording the materials passport of a material in a building, and thereby also establishes the property rights to the materials. This possibility is the subject of Chapter 4.

- In addition to the instruments that can be used to make an inventory, other activities are needed as input for the inventory. These include site visits, virtual visits, building information and data collection, and audits related to toxicity and hazardous materials.

- About a Site Visit, the following input is required:
• Prepare the visit with plans about the building (paper or tablet), maximum information about the building and the existing products, aimed at products to be evaluated.
• Prepare the planning of the visit with the building owner to optimize the results of the inventory, to have easy access to the local situation, to have light, to access the elements, etc.
• Be with two people with at least one construction/reuse expert.
• In some cases, use the visit to scan.
• Take pictures of the products and the location of these materials.
• Try to look behind elements to see connections and hidden products.

- The following input is required for a Virtual Visit:
• Provide access to project stakeholders. Provides simple guidelines for using instruments and applications.
• Organize a short presentation when there is an online meeting, in which the tool or building is presented.
• Communicate about the possibility of virtually visiting the building for potential buyers/users of the (reusable) products.
• Ask the contact details of the persons and organization who want to visit the building. Get feedback on elements they are interested in.

- About the collection and consultation of existing data about the building, the following input is required:
• For a site visit it is necessary to consider all available information about the construction of a building. This information allows an initial assessment of the construction components and their compatibility with a reuse process.
• The main sources of information are technical and regulatory audits, plans and drawings, technical documents about products, tenders, information about renovation projects, history of the building.
• Ask the building owner to collect all available information he has internally and, depending on the typology of the building, search for historical information in public records. If necessary, you can also contact the architectural firm that supervised the construction.
• Use existing tools to search for information in many documents (ex MASSDOC).
• Create a repository (cloud) and a glossary for all collected documents.
• Additional RBIM assessment requires date of construction, specification of refurbished parts and individual details of each renovation.

- About mandatory audits (hazardous material, waste, etc.), the following input is needed:
• Conduct mandatory audits for the project (lead, asbestos, hazardous waste, C&D waste, etc.).
• Ideally, do this before the on-site inventory to avoid contact with hazardous materials, locate recoverable products, and integrate all data into approach support tools.

• Contract specialist/authorized auditors.
• Ask for details on the specific presence of hazardous products, contact with other elements, photos, if possible
• Create a repository (cloud) and a glossary for all reports.

3.3. PRODUCTS AND SERVICES

3.3.1. 3D scanning
The 3D Scan is the first step in the creation of the digital twin of the building to be deconstructed. Laser scanning has been around since the 1960s. But the first 3D scanner used by surveyors and engineers appeared in the late 1990s. One of the main advantages of using a 3D scan is that it is fast and accurate enough to give the best realistic view of an entire building. The DDC project uses the mobile scanner VLX (manufactured by NavVis), which scans (or maps) approximately 10,000 m² per day. And at the same time, many panoramic photos of the building are taken.

After processing the raw data, the building can be visited virtually via a web browser. The end users can virtually visit the building and manually add information to a part of a building and share this information with the other stakeholders. They can take measurements related to the point cloud or update and download part of it.

During 3D scanning, a lot of geometric data is collected (point clouds and panoramic images) that can be used to automate the inventory of a building. Computer animation is used to automatically identify the assets (doors, windows, lights, sensors, ...) and to geolocate them with the Indoor Viewer. The point cloud is used to create the Reversible BIM model and asset list to provide accurate information to the material database.

3.3.2. Reversible *BIM (RBIM)*
The Reversible BIM module is a BIM application based on Durmisevic's model. The RBIM is based on a recorded point cloud (from 3D scanning). Using the Revit digital reversibility assessment plugin, RBIM enables the reconstruction of the digital model of the existing building. An analysis that includes the spatial dimensions, material relationships, quantities and reversibility and reuse properties of a building and its components.

A Reversible BIM has two integral characteristics:

- A. Digital parametric representation of buildings with information about geometry, position, function, relationships, and connections between building elements.
- B. The Digital Reversibility Assessment (DRA) provides an assessment of reversibility/removability/reuse potential. This was developed to assess how easily building products and materials can be recovered without damaging surrounding components.

The Reversible BIM module is therefore a digital application for the assessment of reversibility and dismantling of buildings and construction products. This results in the calculation of the reuse potential of construction products and materials. At the same time, RBIM stores and manages data on building materials, life cycle, functions, dimensions, volume, embodied Co2 and reuse potential in a BIM environment. An environment that allows for micro and macro analyzes of the circular capacity of the building and its material over the life of the building. As such, the model generates information about:

- several deconstruction/repair steps of building materials,
- the degree of damage to material after recovery,
- the potential score for reuse,
- the effort required to recover,
- the re-applying of materials that indicate the ecological and economic value of recovered materials.

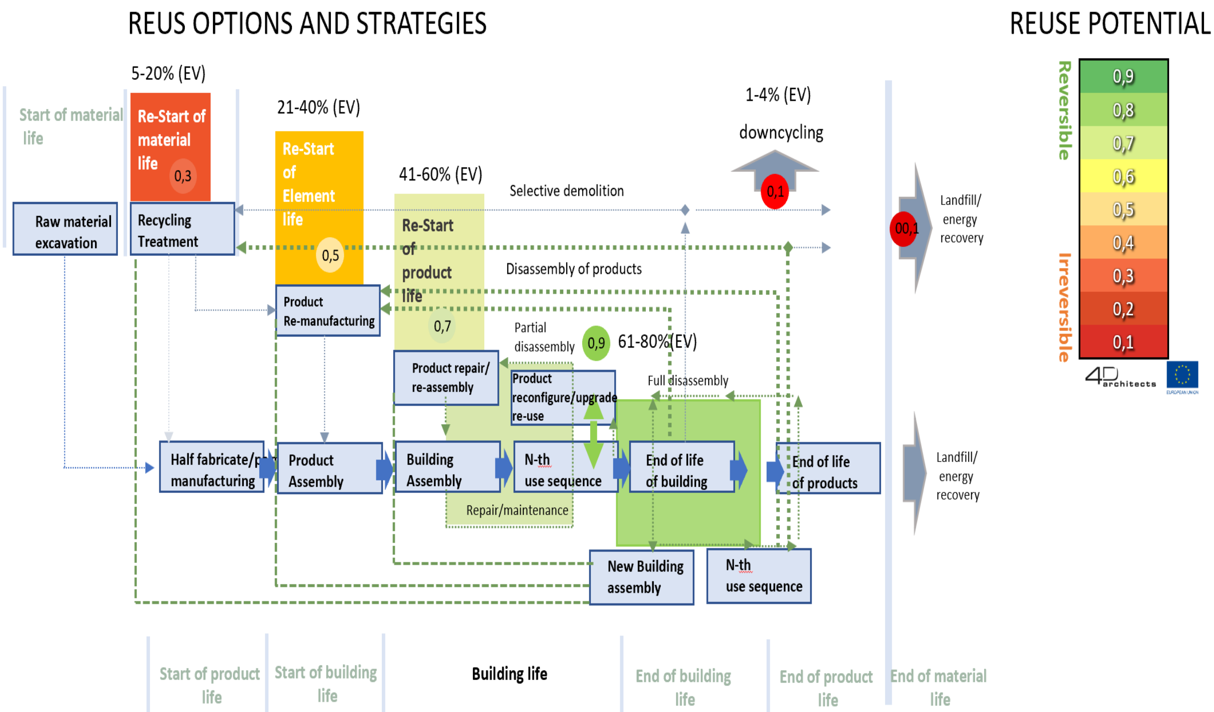
The removability and reversibility assessment are performed at three levels of the technical composition of the building (i.e., building, system, and component level) (Durmisevic 2019, 2020).

The Reuse Potential (RP) score, based on a digital reversibility calculation, ranges between 0.1 (worst) and 0.9 (best). She sorts all building elements into three categories:

1. Irreversible buildings (building elements/materials with low reuse potential, materials are in a deteriorating cycle towards recycling and downcycling),
2. Partly reversible buildings (partial reuse potential, materials can be remanufactured or reused after major repair and
3. Reversible buildings (buildings whose materials can be reused immediately or after minor repair or reconfiguration).

The reversibility of buildings indicates the possibilities for reuse of products and materials after they have been recovered. Since it measures effort and time, the model also considers the number of disassembly steps and operations required to restore an element. The models are the result of a solid foundation for environmental and economic assessment of dismantling and recovery activities.

The shorter the feedback loop of the life cycle of a construction product, the lower the environmental and economic impact and therefore the higher the score for the potential for reuse (see figure below). This calculation system is based on Model Durmisevic published in 2006, updated in 2009 and evaluated and verified during EU H2020 BAMB-Buildings as Material Banks Project (Durmisevic, 2006), (Durmisevic, 2019).



3.3.3. The digital materials database

The Digital Materials Database is an IT application that stores information about materials in a building in material passports. It makes information about all materials transparent so that every owner knows what he owns in terms of materials and the quality of these materials. The Digital Materials Database can be seen as a support system for making a cost-benefit analysis for reuse of materials, by storing all information about this analysis, or by providing statistical data resulting from previous inventories and analyses.

How to use and enter information in the materials database?

A Materials Database gives materials an identity. For this, each material must have its own passport. This passport stores information about the materials in a building, which is obtained by inventorying each material through 3D scans and manual activities. Normally, inventory activities are performed by people with knowledge about buildings and materials that walk through the building and "write down" the materials they see on each floor and in each room. Activities that can be supported with 3D scans, RBIM models and drawings of a building.

The Digital Materials Database used in the Digital Deconstruction project, Cirdax, has an inventory support application that makes it easier to enter information about the materials. Property owners, their staff, or a specialist advisor can learn this inventory process with about two days of training. Normally, a training to learn to use Cirdax starts with only one room and only a few materials to register. An example that can also be prepared in Excel. In addition, material properties in terms of size, weight, color, location in the building, etc. are given a place in the passport, as is the notification about the removability of the material from a building. Information collected from the Reversible BIM processes. The Reuse score of a material is an integral part of the passport and tells us whether a material can be used alternatively, including an adjustment for the cost of disposal and processing for alternative uses.

How to use and exploit the output?
The Materials Database provides the owner of a building and the materials in that building with information about the materials in terms of quantity and quality, which can be combined economically and financially. It provides information on the economic, social, and financial value of the materials, which is used on the benefit side of a cost-benefit analysis. By economic value we mean the sum of both the financial and social/environmental value of the materials.

Registering each material in a materials database is economically feasible for all materials that can be removed from the building easily or with moderate effort according to the reuse score in the RBIM-analysis. For those materials that require a great deal of effort to inventory, register, store and sell, it is necessary to perform a (minor) cost-benefit analysis. In addition, it also provides a transparent picture of the quality of the materials and the costs involved in inventorying the materials and processing them in such a way that the materials can be used alternatively. Performing a manual inventory is described in Handbooks. This inventory is a professional process conducted by an expert regarding materials in a building and of a building itself.

The inventoried data from a manual or automated inventory can be included in a digital materials database, such as Cirdax. This data can then be used again by the application of APIs related to data exchange. The registration of a materials passport in the Euthereum blockchain is used to register property rights. That is, a digital link has been made between the Digital Materials Database (in the DDC project Cirdax) and the Euthereum blockchain using APIs on several servers. For each material stored in the digital materials database, a materials passport has been generated with a blockchain identifier (#hash). This #hash can also be found on the Euthereum blockchain.

Through a verification process using the blockchain, the underlying characteristics of the material in the material passport can be continuously verified and changes to the material passport can only be legally valid if the characteristics of this updated material passport has been added as a ledger line in the Blockchain again. This gives each material its own demonstrable identity, which can serve as a product for further implementation of costs and benefits, because other rights can now also be linked to these rights. See chapter 4 in this handbook for more information.

3.4. Techniques, Templates and Tools

a. A description/guide of the point cloud scanning process with NavVis.
b. A description/guide of the RBIM process with the Revit plugin.
c. A description/guide of the manual inventory process.
d. A Guide to Using the Digital Materials Database, e.g. Cirdax.
e. A Guide to Using Blockchain Integration with a Digital Materials Database

3.5. RESULTS

3.5.1 3D SCANNING

The 3D scanning results in a series of point clouds and panoramic photos, which are stored in a database or cloud and can be used as input to the Reversible BIM. The various data can be studied using a web browser or 3D viewer.

3.5.2 REVERSIBLE BIM

The Reversible BIM output and sub output can be displayed as follows:

- A. A color coded 3D viewer, showing the degree of reversibility and reuse of construction products/materials by color.
- B. Raw data: material and reversibility properties for each material, e.g., ID, type, material name, function, potential for reuse, building level/floor, volume, tonnage, carbon embodied, waste avoided, carbon avoided, material recycled, material group, number of connections, type of connections, number of disassembly steps.
- C. Reversibility Summary and Potential Data Table for Reuse:
    - 1. At building level: global total (average reversibility and reuse potential score of all materials in the buildings) total volume, tonnage, CO_2 embedded in the buildings, average avoided waste.
    - 2. At system level/building function level: reuse potential, avoided waste, CO_2 per function such as: Capacity, Housing, Separation, Finishing, Equipment, Intermediate, Vertical communication.
    - 3. At product/element level: reuse potential, avoided waste, CO_2 per product type and number of products, e.g., facade column x, doors y, doors z, steel profiles x etc.
    - 4. At material level: potential for reuse, avoided waste/reusable tonnages, CO_2 per material type e.g., aluminum, steel x, wood mdf y, concrete z, bitumen etc.

- D. Overview of raw data of products/materials according to the possibilities for reuse, for example:
    - 1. products and materials that can be directly reused or minor repairs,
    - 2. materials that can be reused through major repair or remanufacturing,
    - 3. materials that can be reused by recycling,
    - 4. materials that have no reuse option

- E. Summary tables indicating the disassembly effort for each building element, including:
    - 1. number of connections,
    - 2. type of connections,
    - 3. number of disassembly steps per building element

- F. Score per potential indicator for reuse such as:
    - 1. Reversibility of connections,
    - 2. Number of relationships,
    - 3. Hierarchical Dependencies,
    - 4. Disassembly sequence
    - 5. Remaining life cycle/life cycle coordination

- G. Summary Data Chart:
    - 1. Breakdown of embodied tonnages of material and carbon by material and building system/product and by category of reuse option. Built-in tonnages vs reuse of material/waste avoided by category of reuse option
    - 2. Embodied carbon vs avoided carbon by category of reuse option

- H. BIM Objects: 3D digital library of reusable elements.

- I. List of hazardous substances: e.g., asbestos, lead, chromium 6, etc.

- J. List of damaged materials

How to use and exploit the RBIM outputs?

1. RBIM outputs are multi-layered and can be used as decision support by different stakeholder groups.
2. RBIM output provides information on quantities, volume, weight, per material and product type, including their “embodied Co2”. As well as the Reuse Potential Score that is reflected in the indication of avoided tonnages of Co2, waste and raw material, as well as the reuse options of materials.
3. As such, RBIM output is used to develop reuse strategies and define a more detailed circular ambition, which is then integrated into tender documentation and requirements for the constructor.
4. The calculations reflect the effort required to recover material, as well as the repair effort required to reapply material.
5. The calculated value reflects potential labor, equipment and new material required to recover and reuse harvested material. Therefore, RBIM results are also used for the preliminary elaboration of the most desirable reuse options for a given economic objective of the project.
6. Based on a library of reusable materials, the building owner can purchase materials before demolition begins.
7. RBIM results provide information about the position of elements to be recovered, as well as disassembly steps and operations indicating that an element can be easily recovered. This is used to develop deconstruction and sorting strategies.
8. Reversible BIM creates a digital library of BIM objects from reusable elements, allowing architects to start using reusable elements in their modern designs before the building is deconstructed.
9. The digital library of BIM objects of reusable elements is used by manufacturers who remanufacture and refurbish reusable elements. BIM objects are then used by manufacturers as part of the sales catalogs.

Government agencies
The digital reversibility assessment score reflects through its score the building's ability to enable a circular material feedback loop. As such, RBIM defines a circularity profile of a building and classifies all buildings into 5 circularity profiles from irreversible to fully reversible building products and materials. This is used by governments to standardize the performance of circular buildings, define circular ambitions through a building code and smooth the transition from linear to circular economy in construction.

3.5.3 THE DIGITAL MATERIALS DATABASE

The results of the various inventory processes of the varied materials in a building are registered in the digital materials database. This provides insight into which materials are present in a building. Using the various metadata that can be linked to a material registration, each material is given an identity. For example, attributes related to size, quality, removability, etc. can be added to this identity.

By linking the registration of the materials to the blockchain, the materials also get a strongly defined and recorded property right. This, in turn, can be used to tie the rights to these materials with the ability to sell the materials on a marketplace. Or to arrive at a material balance of a building based on the sum of the rights of these materials. Or to link these rights to other rights, such as CO_2 emission rights.

3.6. QUALITY FACTORS

One of the best-known problems with the reuse of materials is that a new user often does not know which quality standards a used material still meets. By inventorying the characteristics of a material and recording it in a digital materials database, this form of asymmetric information is eliminated. That is why a material is given a quality basis again, which can be used for further reuse. This issue was originally described in: George Akerlof, The Market for Lemons, 1970.

3.7. PROCESS ACTIVITIES

3.7.1. 3D SCAN

A. 3D scan on location
• Evaluate whether a 3D scan is relevant to the project. It may depend on the building typology and size, budgets, distance from the building to stakeholders, support, and management teams. Talk about the issue with support and project management teams.
• Determine the expectation for the 3D model: integrate the 3D model into a BIM program, allow a virtual visit, allow to add POI, communicate, provide a technical tool for the project management team.
• A resolute service provider experienced in reuse approaches can provide point clouds and segmented 3D models. And ideally a 3D viewer that is easily accessible/usable.
• Determine the time when the 3D scan can be made ideally it should be made when the building is empty, so that the building appears on the 3D scan as it will be at the start of the demolition.

B. 3D model viewer, add info and POI
• Choose a relevant tool that has been evaluated before, or that has already been used. A tool that has experience with reuse approaches. Preferably ask the opinion of previous users.
• Preferably choose a tool for which you can give stakeholders free access to your project.

3.7.2. RBIM

A. 3D Model Segmentation – BIM
• To be performed by the service provider unless the expertise is available internally.
• Define with the service provider the required level of detail, the use of the 3D model and other tools used.
• Define intermediate stages in the process where the consultancies (architects; engineers) can view the ongoing segmentation of the building to see if the defined goals are still realistic or need to be revised.

B. Stock. First level of information
• The information level must be estimated depending on the importance of the products for reuse. Do not waste time detailing products that are impossible to properly deconstruct or reuse and focus on all products with potential.
• The information required depends on the various products and materials in a building. General: product, material(s), condition, dimensions, brand and reference of the product, location in the building, photo, number, + if possible and useful: info about disassembly, reuse.
• If digital tools are used for the rest of the process, use the digital materials database to record the various data resulting from an inventory.
• In case RBIM is applied for the inventory of reversibility/disassembly and reuse potential, the above information about the number of products, their dimensions, disassembly potential is automatically generated from RBIM.

C. Tests on disassembly
• Not mandatory, but ideal in some cases.
• Disassembly testing allows to identify the best method of deconstruction to maintain product integrity. If possible, try to observe the potential of physical disassembly during the visit, or the later visit organized after product identification.
• Organize a specific visit with the dismantling company. They can provide an expert view and advice.
• Drawing up a contract for the disassembly tests.
• The time for disassembly testing must be provided in the project planning (see "program for the project."

D. Detailed Inventory
• Fill in the inventory with all the information found, including the tests.
• If digital tools are used in the process, use the digital materials database to record the various data resulting from an inventory.
• The level of detail can differ according to the function of the desired products and their reuse potential.

• The detailed inventory is supporting information that many actors need throughout the process. It must be accessible and up to date.
• Give access to the inventory to all actors of the project. Provide a usable and understandable database and/or tool. Provide guidelines for the use of the database and tools if necessary. If a commercial tool is used, provide free access to stakeholders.
• Provide a synthesis of product quantities/typologies, etc. to collaborate with actors using general and understandable data.
• Communicate the inventory to the target network to find potential buyers and users. For example, with the help of a digital marketplace.
• Update information with stakeholders' products and interests, products sold, deconstructed, and attached documents.

E. Evaluation of reuse potential (RBim)
• Contact experts to know the terms of an RBIM assessment and access to an RBD (Reversible Building Design) platform with guidelines and protocol.
• Gather all necessary information. As previous results on the Digital Deconstruction project.
• Preferably provide a segmented 3D model that can be used by experts.
• Discuss the objectives of the assessment, define the intended products / parts of the building / desired ambition about CO2 reduction, avoidance of raw material use / desired ambition about material reuse and waste disposal.
• Use the color-coded 3D reversible model viewer within NaVvis to visualize reuse options of construction products that correspond to the color code and their distribution throughout the building.
• Use the overview of materials with high reversibility/disassembly and potential for reuse and information on the dimensions, quantity, embodied CO2, product positions to investigate the market and industry conditions for their repair or processing.

F. How do you make an RBIM of a building?
Creating an RBIM for deconstruction projects starts with collecting point cloud files from 3D scanning, engineering drawings and bills of materials, if available. Based on this data, a basic Reversible BIM representation of a building is created according to the RBIM modeling protocol. Once a base model is created, the reversibility and disassembly of the parts is analyzed using the RBIM plugin. This plugin creates an automated view of the number and type of relationships elements have between each other and hierarchical dependencies that create obstacles to a smooth recovery.

RBIM Plugins assess indicators that reflect the reuse potential of individual elements, such as:
• Number of relations
• Hierarchical dependence on individual element
• Type of connections and degree of damage
• Assembly/disassembly sequences
• Life Cycle Coordination
The final reuse potential is calculated considering different weighting factors of the above-mentioned individual indicators about the reuse potential.

3.7.3. DIGITAL MATERIALS DATABASE

When making an inventory of materials in a real estate object and registering the characteristics of these materials in a digital materials database, the following process activities are discussed:

a. Collecting drawings and other documents related to a building
b. Capturing those elements of a building that are already known or not yet known.
c. The physical or digital inventory (3D-scanning and RBIM-analysis) of the materials in a building as a supplement to the preliminary analysis.
d. Recording all data in a digital materials database.
e. Creating a materials passport from a material. Providing an identity to a material in a building.
f. Recording the materials passport in the blockchain. Providing a verifiable identity to a material in a building.

3.8. QUESTIONS AND ANSWERS

The following questions have been asked in projects on this subject. Every question has an answer:

Have you used the Indoor Viewer?
Respondent 1: Yes, we have used the Indoor Viewer to check some objects after we received the review from our design team.
Respondent 2: Our architects received all data by email and used their own drawing program to load the data and extract vector plans from it (plans, measurement plans, etc.) to provide clear plans within the public tender. The building owner has checked the data once in the Indoor Viewer.
Respondent 3: Yes, we used the Indoor Viewer to check some objects after we received the review from our design team.
Respondent 4: Yes, we used the Indoor Viewer to present the station. It is an uncomplicated way to explore the building without moving. The scan was made late, otherwise it would have been especially useful for the reuse diagnosis.

Did you use the measuring tool? If so, what is your feedback?
Subject 1: Yes. Quite easy to use and convenient

Have you shared the Indoor Viewer with other stakeholders?
Respondent 1: Yes, with our design team (responsible for resource assessment and reuse/recycling strategy)
Respondent 2: Yes, with the owner of the building
Respondent 3: Not yet, but we will include this link in the public tender documents so that contractors can virtually walk through the buildings.
Respondent 4: Yes, with our design team responsible for resource assessment and reuse/recycling strategy.

Which functionalities do you want to add in the Indoor Viewer?
Respondent 1: The ability to associate a Point of Interest with a file.
Respondent 2: It would be interesting to associate a Point of Interest with a description in the material database.
Respondent 3: The item recognition would be especially useful.

What are your preferences?
1. Create RBIM yourself or by an external expert and use Revit for the digital reversibility assessment?
2. Only interested in output presented in tables and exported as Excel files for further own data analysis?
3. Only interested in data as stated in question 1 in PDF format and graphs?
4. Interested in all forms of output and RBIM use?
5. Are there one or more Reversible BIM outputs you can think of that should be added to the list of outputs?

Respondent 1: In the case of old buildings, it can be interesting to indicate the heritage value and to see which materials - in whatever condition - must absolutely be preserved (for example to restore afterwards)
Respondent 2: We would like a written explanation of all the charts and advice to develop a strategy because at this point we do not know how to use that data. The output of RBIM must be analyzed to produce a reuse strategy adapted to the project. How do you do this?

Are there any material properties you can think of that should be included?
Respondent 1: Heritage value, age of the materials, necessity for conservation (due to, for example, the unique character of an old valuable material)
Respondent 2: In a manual reuse diagnosis, we look at the disassembly potential, but also at:
- The quality of the material: is it old? Has time damaged it? Is it healthy?
- Is the material easy to transport and store without damage?
- Is it an element that can be easily reused (element wanted, minor repair needed...)?

Which properties of materials in a building are important to you, so that they can be included in a materials passport?
Respondent 1: Geometric dimensions, Material, Weight, Technical specifications
Respondent 2: Heritage value, age of the materials, conservation need, number, dimensions, condition, certificates, loose parts (in suitcase), weight, location, how the material is connected to others, special points of attention when removing the material, route to storage.
Respondent 3: For one building (e.g., 1000 windows) how many are reusable (e.g., 600 windows can be reused and 400 not because there is damage)? How to dispense the material without damage? How to store the material without damage? What are the material dimensions? What is the material weight? What is the main ingredient?

How is the quality of reusable materials in your company determined or recorded? Is a distinction made here between reusable own materials or reusable materials from third parties?
Respondent 1: Based on the question that arises (no determination of technical quality such as performance tests). No reuse for our own needs.
Respondent 2: Not yet included, but I think our architect team will check the quality on site. If necessary, specialized companies can conduct tests.
Respondent 3: The quality is determined during the reuse diagnosis. There is no difference between reuse for us or for third parties.

Is quality not part of your way of working and are materials only recycled in low quality?
Respondent 1: Currently, recycling is mainly "downcycling", not real reuse.
Respondent 2: Until now, materials were only reused for downcycling, but we want to change that.
Respondent 3: No, we want to reuse our materials!

3.9. COMMENTARY

The following comments can be added about this chapter.

1. *From the various questions to Project Owners within the Digital Deconstruction project:*

• The Digital Deconstruction project and its platform should set 'a standard' for stocks of materials in buildings.
• Inventory: that material properties, the way of dismantling and the advice for where to go can additionally be added to the "basic data" (dimensions, location, description, etc.) in a digital materials database.
• It must be possible to search by quantities of materials with the Digital Materials Database.
• For an RBIM analysis you need to know a lot more (and look behind the curtain): connections, knowledge of materials.
• One must have the possibility to use the DDC modules independently, and not be obliged to use the BIM-Y 3D model and/or RBIM.
• One should have the ability to integrate small pieces of information into the inventories and studies (some have value).
• CSTB: in connection with waste audits (new PEMD in France on the way), a clear distinction is made for the time being between the 'waste audit', which includes all materials, and the 're-use inventory', which only contains reusable elements.
• Creation of new project: possibility to integrate building parts and POI from the 3D scan model directly into the structure of the project to be created. Or create in the platform and link with the POI.
• It would be interesting if the Digital materials database and the RBIM could be linked.
• Genuine interest in adding documentation (documents, links) to the "Material Information" windows.
• Order of deconstruction: it must be good to be able to select/propose several types of valorization value chains.
• It should be interesting to list detailed reuse and recycling of elements.

• Use Cirdax as a detailed material database to provide an overview of all instrument results.
• Use RBIM output tables with an overview of products and materials per building function, product type/material with information about use potential of individual products and material quantities, dimensions and associated avoided CO_2, waste, and raw material.
• Communicate and share the RBIM digital library of reusable elements and their BIM objects with architects, industries, and sales platforms to boost their potential reuse.
• Use RBIM outputs with summaries of materials with no potential for re-use and requiring special treatments.

2. *From the project CB23 (Netherlands)*

A construction passport ('passport' for short) ensures that the correct information is available in the right way when the need for that information arises. The need can be a current need, but the availability can also anticipate future needs. By registering information about the objects, passports support the three pillars of circular construction:

a. Protecting material stocks,
b. Protecting the environment and
c. Protecting value.

High-quality reuse of materials on the one hand and reducing the use of primary raw materials and the production of waste on the other are the primary goals of using a passport. A passport provides insight into which materials were used in the construction and how they were processed. The form of a passport must be unambiguous, but the content can vary.

The information need, based on the available data, is the core of using a passport for construction. For the passport it is important to guarantee the completeness, reliability, and accessibility, and thus the practical usability, of data as well as possible. The data that is discussed in a material passport is about the local context (area, complex) and the nature and composition of the structure itself (element/construction part/component, construction product, material, or raw material). The passport shows the product characteristics and thus the reusability potential during the use phase through use, wear, maintenance, and replacement. On delivery, the data must therefore represent the building as built and as is during the use phase. It is crucial that passport data is reliably communicated to the data portals for reuse when it comes to future availability of building components. They derive their information from this about identity, quality, quantity, and the moment at which secondary (building) materials become available.

3. *Improving data quality*

By requiring a material passport in new and existing real estate and by accurately inventorying and registering buildings on materials, the sector can increase the quality and completeness of data. In the civil engineering sector, the information delivery specifications (ILS) are the correct method to register used materials, by including the materials passport.

To guarantee the highest data quality, it is important that the attributes of construction works are recorded in a passport by experts in that field immediately after completion of a construction or civil engineering object. The chosen attributes must relate to the design or production phase, the use phase, and the end-of-life phase. In this way, data is recorded that is equal to reality, the as-is and as-built instead of the as-planned and as developed of a building.

3.10. REFERENCES

Scientific references

George Akerlof, The Market for Lemons, 1970.

Elma Durmisevic Design strategies for reversible buildings
- URL: https://www. bamb2020. EU /wp-content/uploads ..., 2019

Elma Durmisevic Circular economy in construction design strategies for reversible buildings
- BAMB, Netherlands. [Online] Available at: bamb2020 ..., 2019

EU H2020 BAMB-Buildings as Material Banks Project (Durmisevic, 2006), (Durmisevic, 2019).

References within projects

1. Housing association house in Lomme (F)

Any material listed below has not yet been confirmed to be reusable. So, they do not necessarily need to be properly disposed of for reuse and can often be removed for recycling. Materials that for some reason cannot be reused or because no potential buyer has been identified are likely to be recycled. We are not yet able to draw any conclusions about the amount of material in this list that will be reused or recycled. These are hypotheses.

A. Typology of material to be recycled:
- Floors
- Walls
- Staircase
- Ceilings
- Roofing
- Insulators
- Guardrails
- Sinks
- Kettle
- Radiators
- PO Boxes
- Plumbing
- Bathtubs
- Windows

Key identified materials from the demolition site for reuse and their amount
- Concrete: 887.22 tons
- Steel: 87.46 tons
- Plaster: 27.69 tons
- Soft PVC: 4.92 tons
- Rigid PVC: 3.82 tons
- Glass: 4.15 tons
- Wood: 1.69 tons
- Porcelain: 1.31 tons
- Tiling: 2.22 tons
- Sanitary: 16 units
- Bathtubs: 16 units
- Steel sinks: 16 pieces
- Porcelain sinks: 16 pieces
- Boiler: 16 units
- Mailboxes: 16 pieces

2. Recyclable material from St George Villeneuve. Station

Typology of reusable material:
- Concrete
- Doors (inside & outside) and windows
- Floors
- Ceiling
- High/low voltage equipment (lighting, hi-fi, camera, screens)
- Sanitary equipment
- Heating, ventilation, air conditioning equipment
- Furniture

Key identified materials from the demolition site for reuse and their amount
- Glass: 186m² available. App 83m² to be reused on site as a railing
- Mineral/concrete cladding (Acrytherm Rebeton): 390m² available. Approx. 300m² to be reused on site as interior cladding
- Stone facade: 69m² available. Approx. 55m² to be reused on site as interior cladding
- Wood under roof: 307 m² available
- Ceiling: 430m² available. Approximately 228m² to be reused on site.
- Technical floor: 92m² available.
- Tiles: 160m²
- Ceiling lamps LED 60x60: 49 pieces available. About 24 pieces recycled on site.
- Other lights (Sammodes SNCF): 17 pieces available.
- Other lights (security): 12pcs available
- Kitchen equipment: 2 pieces present. 2 reusables
- Sanitary facilities: 14 pieces (6 washbasins, 6WC, 2 shower trays)
- Radiators: 21 available (16 cast iron and 5 electrics)
- Interior doors: 29 available. 5 reusables on site
- Heating and air conditioning.: 10 units available.

Possible destinations:
Focus on the deconstruction materials identified to be reused in-situ (on site):
- Glass :83m² to be used as balustrade
- Mineral/concrete cladding: approx. 300 m² to be reused as interior cladding
- Stone facade cladding: approx. 55 m² to be reused as interior cladding
- False ceiling: 228m² reusable
- Ceiling lamps LED 60x60: 24 pieces reusable
- Kitchen equipment: 2 kitchens = 12ml reusable storage cabinet
- Interior doors: 5 reusables on site

The main materials that third-party buyers found:
- 307m² wood under roof
- 84 beams and other metal element of the structure
- 34 doors
- 50 m² tiles
- 152 blocks of glass

The following materials are on AREP's internal materials web platform and Cycle-Up's third-party marketplace. The suitability of the materials must be confirmed.

Material from external SNCF projects to include on site:
- Piece of wood to pack and transport SNCF rail crossbar:
o For wooden suspended ceiling: 1106h = 1217ml required
o For wooden balustrade: 869u = 956ml required
In total 6m3 of wood. Storage room of 6m².
- Granite pavement:
o Indoor and outdoor paving: requirement of 632m²: Storage of 32m² (big bags or boxes)
- Technical carpeting from a refurbish actor:
o False technical floor: requirement of 20m²: Storage of 7m²

3.Examples from the British Green Council paper: Insights on how circular economy principles can impact carbon and value

Design for flexibility

1. JLL Office Fit-out: 90% of the floor plate is reconfigurable with fixtures and furniture reconfigurable or dismountable. Minimizing constructed cellular spaces created an active workplace design with no internal partitions. This resulted in, compared to a business-as-usual setup:
    a. 17% CO_2 savings upfront by designing materials and products by adopting an open plan office space design approach, reducing the need for internal partitions.
    b. 23% upfront carbon savings from recycled, where possible MEP (Mechanical, Electrical and Sanitary Engineering) equipment and from designing MEP materials and products needed by adopting an open office design approach by using 35 less fans.

Design for assembly, disassembly and repairability

1. Roots in the Sky: Screwed structural connections take precedence over welded connections where this is structurally and technically feasible. This allows the primary steel material to be reused in future developments. Assuming a 50% recovery rate, this measure has the potential to save approximately 3,500 tons of CO_2 e on future developments.
2. Holbein Gardens: New brick fitted with lime mortar; this can be cleaned so that the stones can be dismantled at the end of their life: With Lime Culture, CO_2 emissions are estimated to be about 20% lower than with cement production; Lime mortar will also absorb CO_2 during the hydration process and become climate neutral over time.

Standardization combined with off-site methods that reduce waste can reduce carbon upfront. But standardization in a design could increase carbon if not applied carefully and strategically. Examples:

1. The Forge: Using a Platform Design for Manufacture and Assembly (P-DfMA) means the project is on track to achieve an embodied 25% upfront carbon reduction over a typical newbuild baseline. Standardized products increase site productivity and reduce construction time, leading to a reduction in site emissions
2. 80 Charlotte Street: Prefabrication of the facade with precast modular installation and other structural elements (pipelines and ceilings) resulted in reduced waste, construction impact and labor on site. This also saved construction time.
3. JLL Office Fit-out: Standard sized materials implemented to minimize construction waste; along with waste design, there was a 14% upfront CO_2 savings compared to baseline from transporting fewer materials, products, and waste, as well as less energy required on site due to fewer materials and installed products.
4. Blackrock Street: using wood and pre-insulated exterior wall panels and floor cassettes in a 'flat pack' MMC (Modern Methods of Construction) approach took the construction of the building into the air in a matter of days There was a reduced CO_2 impact due to the use of wood. This was also cheaper than traditional fabrication.

Using gentle impact materials can result in buildings having a lower LCA than renovating the existing building. Examples:

1. The Enterprise Centre: local natural materials (Norfolk flint), hemp fabric, Sonaspray, Warmcell, clay plate, locally sourced wood frame and straw cladding, solvent-free paint, linoleum, linseed, and jute mats on recycled glass screed: overall, the project epitomized 65 % less carbon than a conventional higher education building (at the time).
2. Blackrock street: Using wood as the primary building material saved 102 kg CO_2 e/m2 (if storage is included).

The use of recycled material in the cement can lead to a lower initial carbon

1. The Enterprise Centre: 70% GGBS (Ground-granulated Blast-furnace Slag) in the concrete gave an embodied carbon reduction of 62% compared to typical cement concrete.
2. 1 Triton Square: Replacing an average of 65% cement with GGBS yielded an embodied upfront carbon savings of 665tCO_2e compared to 30% PFA (Pulverised Fuel Ash).
3. The Forge: GGBS 50% in substructure and 40% in superstructure resulted in 40% carbon reduction in the substructure and 22% carbon reduction in the superstructure compared to typical cement concrete.
4. Cambridge Avenue: Recycled concrete specification saved 200tCO_2 e (63kgCO_2 e/m2).

The use of recycled paint can lead to a lower pre-carbon content

1. The Entopia building: 165 liters of paint (25% of the paint used) contained 35% recycled paint, a saving of about 10% embedded carbon compared to a comparable product.

Using recycled floors can lead to lower initial carbon

1. Timber Square: Reclaimed raised access floors have about 20% more carbon than new.
2. 80 Charlotte Street Furnishings: Recycled content in carpet saved 67 kg CO_2 e/m2 carpet surface (22tCO_2 e) than a less environmentally friendly option from the same manufacturer.

Using recycled glass can lead to lower initial carbon

1. The Burrell Collection: Using a closed glass recycling approach, over 16 tons (over 16%) of glass were processed into cullet to produce new architectural glass; saving of 5 tCO_2 e.

Using recycled plastic can lead to lower initial carbon

1. Blackrock street: 100% recycled plastic drainage, formwork and separation joints reduced the need for concrete, saving 17 tCO_2.

Designing waste is an easy gain for CO2 reduction, although it can be challenging to quantify. Waste design is closely related to design for flexibility and adaptability and can often aid disassembly and reparability, especially for components or materials that are subject to changing tastes (e.g., Cat A or B fixtures where the tenant will have significant changes apply to suit his style)

1. The Entopia Building: Avoided finishes on raised access floors to reduce embedded carbon; galvanized steel surface floor cleaned and exposed in some areas to reduce embodied carbon; (this is linked to reuse of the original floor - Reuse of existing raised floor saved 32 kg CO_2 e/m2 (or approximately 85,000 kg CO_2 total) compared to using new raised floor panels).
2. 80 Charlotte Street Fittings: The entire design minimizes finish where possible, using exposed ceilings with acoustic panels and aluminum clad exposed fixtures - a saving of 346tCO_2e compared to a suspended ceiling.

3. JLL office furnishing: Material saving, design with visible features avoided the use of suspended ceilings, which in combination with an acoustic soffit spray provided acoustic comfort. This resulted in a 66% carbon savings compared to the recessed housing due to low carbon decking products, exposed ceilings, and the reduced number of internal partitions, requiring additional finishes.

Shortened construction programs have the potential to reduce site impact, which could potentially be achieved through standardization:

1. Timber Square: dry construction techniques, minimization of wet site operations, e.g., raised access floors with minimal screeds. Minimization of internal materials such as omitting a complete suspended ceiling. Erith conducted a study prior to demolition to explore how to maximize recycling of demolition and excavation equipment: the impact on construction has been reduced by approximately 50% compared to a typical office.
2. The Forge: On-site production reduces on-site material waste.

4. Transfer of Rights to Materials

4.1. Introduction

The Blockchain Module provides a tool that enhances the use of the Digital Materials Database. It is only effective if it can be used in combination with a Materials Passport. Each Material has its own Material Passport, which gives this material its identity. The identity can be verified by registering the ownership of the passport in the blockchain, which also gives the possibility to see that registration as a property right at the time of registration. The blockchain registration serves as a property right that is also included in the materials passport by means of its hash, i.e., the blockchain identity of the materials passport.

With the blockchain registration, ownership rights to the materials are established. Proprietary rights allow us to link these to other rights, such as Co2 rights, or to sell these rights to other interested parties. The combination of materials with an identity, the verified blockchain registration and the characteristics of property rights, gives us the opportunity to link materials to marketplaces and future contracts, because the immutable nature of information in the blockchain can also manage things like liability and term contracts. We always know who owns the materials.

4.2. Input

The following inputs are required to organize the blockchain registration:

- the material passport of any material stored in the Digital Materials Database

- the server infrastructure for the APIs between the Digital Materials Database and the Ethereum Blockchain

4.3. Products and Services

The blockchain registration gives each material a property right, which can be used to organize contracts, liability, track-and-trace capabilities, and all other information features to use as a legal framework for the reuse of materials.

4.4. Methods, Techniques, Templates and Tools

For assigning property rights to materials, the Ethereum blockchain is used, combined with the digital materials database. A manual is available to guide the user through blockchain registration of material passports.

4.5. Results

An important topic for strategic use of materials are the materials in a building itself without having to be removed immediately. In a classical way of thinking about materials, these materials cannot be used as alternatives and have no value. However, by attaching a proprietary right to each material (blockchain registration), the ownership rights or options on the ownership rights can be given a different owner. This provides the strategic choice for the tripartite division of land, building and material and can lead to new choices in the handling of materials, because materials in buildings can then also be given a different (specialized) owner separately from the building. In this way, the future reuse of materials can also be prearranged in the form of contracts, including the issue of liability if something goes wrong with the materials. In this way, there is a strong incentive to prevent damage or waste of materials, including the social waste of the production of new materials in the form of CO2 emissions during production.

The above option fits into the strategy of an organization and other real estate owners in the field of circularity and is organized using the Digital Materials Database and the Blockchain module. This can lead to different strategies, which only become effective later. One of these strategies is to see products as a service (PaaS) (see also Chapter 2). The costs and benefits of these activities are part of the organizational costs. The benefits of these activities become visible in advance in the proceeds from the sale of materials from buildings, or the circular construction method for new construction.

4.6. Quality Factors

A blockchain registration makes it possible and affordable to guarantee the property rights of materials. This solves quality problems caused by asymmetric information, as described by Akerlof in the Theory of the Lemons. The ability to track and trace material usage using the combination of the digital materials database and a blockchain record also helps with this quality and ownership issue.

4.7. Process Activities

Within the DDC project, a link has been made between the Digital Materials Database and the Euthereum blockchain using two APIs, i.e., connection parts between the database and the blockchain. These APIs are accessible via the Digital Materials Database and form a separate chapter in this database. It allows the owner of the data in Digital Materials Database to add a hash to their information. This hash or blockchain ID fulfills the role of enabler between the Digital Materials Database and the blockchain is organized in an automated manner. The manual for the Digital Materials Database and the Blockchain modules shows how this works. With access to the Digital Materials Database, anyone can also perform the blockchain registrations.

4.8. Questions and Answers

The following questions and answers can be added to this chapter.
No questions have yet been asked by users of this Handbook about this chapter.

4.9. Comments

The following comments can be added to this chapter.

1. Interoperability and Linked Data in Material Passports (from CB23)
If a materials passport can be defined as the combination of different pieces of data with different origins (product data, usage data, data on availability for reuse, etc., but also associated information models), then it is necessary to be able to connect this

heterogeneity of data smoothly. By means of independent standards in software applications, the long-term interoperability between different digital systems of various stakeholders can be guaranteed. The main requirement for digital systems for creating and managing a materials passport is therefore the ability to always exchange data according to such 'open' standards.
Interoperability and linked data in the underlying ICT infrastructure regarding material passports ensure effective and efficient cooperation in the chain of reusable materials. To keep the content of exchanged changes in a passport dataset, including the external product data, irrefutably verifiable and to protect them against data loss, it is obvious to use 'ledger systems' such as a centralized ledger (e.g., government administration) or consider distributed ledger systems (such as blockchain) combined with data set hashing.

To prevent data loss, for example due to the temporary or permanent loss of an online dataset from the primary source, copies of the dataset can be kept. The technical elaboration of ledger systems and measures against data loss are not included in the documents of CB23, but have been realized in the Digital Deconstruction project.

2. Responsibility and liability of building materials products (from CB23)
Manufacturers play a significant role in developing product performance for subsequent product use cycles. For the future reuse (to preserve the value of products for subsequent cycles), the use of secondary and biobased materials (to conserve material stocks), the reduction of CO2 footprint, and to protect the environment. It must also be possible to introduce an obligation via an Extended Producer Responsibility (EPV) as it already exists in other sectors for construction products. And could be conducted with the help of Blockchain registrations linked to a materials passport.

Such an EPR for producers should cover:
• Return guarantee: manufacturer issues a return guarantee on application and material level. In it they state that the product will be returned with the conditions.
• Releasable details: the manufacturer provides details so that the product is releasable and suitable for reuse/high-quality recycling.
• (Disassembly/re) assembly manual: this manual describes how to apply the product, so that it is suitable for reuse/high-quality recycling in the second cycle.
• Maintenance instructions: this sets out the building owner's obligations to extend the life of the product by keeping the product in proper condition.
• Materials passport/BIM model: manufacturer ensures that data is available for future use.

In addition, requirements can be included in specifications for buildings that products and/or manufacturers of building materials should comply with. The following points can be considered in this regard:
• The product must be inspected in accordance with the circular performance and must have a KOMO quality statement and KOMO attestation with product certificate.
• Certain percentages of secondary material based on industry opportunities.
• A certain degree of recyclability based on options suggested by the sector. • The manufacturer must have an LCA of the product in which scenarios for future reuse have

been investigated. For the most efficient scenarios (leading to a lower EQI) the manufacturer must provide relevant performance requirements.
• The manufacturer must offer an effective solution for recycling construction and demolition waste from the product and for demonstrably high-quality use of this waste. The aim is to create your own cycle.
• The manufacturer must issue a take-back certificate for the project.

4.10 REFERENCES

Scientific references
Passports Guide for the Construction Industry Part 1 + 2 Working agreements and substantiation for passports in a circular construction sector Platform CB'23 June 2022

References within projects

1. Examples from the British Green Council document: Insights on how circular economy principles can impact carbon and value

Technology-based products can lead to lower initial costs for owners to pass on to tenants, or financial savings with lower bills and lower operational energy consumption:
» eLight: Cost savings for consumers through lower operational energy costs: £19,841 for one school based on comparison with bills before installation of modern technology. Lower up-front costs for developers.
» If considered at this early stage of a build-to-sell project, PaaS is efficiently integrated, which is more effective than reactively installing new kits and contracts after the building has been sold. Free repairs and maintenance for high-quality interior products.
» Ahrend: Free repair, for an investment of € 45,000 in the working environment, with an estimated saving of approximately € 6,000.

5. SOCIAL VALUATION OF THE REUSABLE MATERIALS

5.1. INTRODUCTION

Reusable materials have both a social and a financial value. The social value of materials is broader than the financial value of materials because the social value also includes those qualitative benefits that cannot be directly determined in monetary units. An example of these externalities is the value of saved CO_2 emissions, which go hand in hand with the reuse of materials from a building, because the reuse of materials avoids the creation of new materials and does not further harm the environment.

Materials can only have a value if these materials can be used alternatively. That is, they can be detached without much damage, and with complete information for the buyer and seller can be re-purposed in a real estate object. In this chapter, the social valuation of the reusable materials is further explained and explained.

5.2. INPUT

To arrive at a social value assessment of reusable materials, the following input is desirable:

a. The different properties of a material
b. The quantitative size of a material
c. The degree of removability, i.e., the alternative applicability of a material.
d. Limiting characteristics of a material for reuse.
e. The property right or the blockchain registration of the materials.
f. Calculation methods about the "embodied Co_2" of materials.
g. Valuation methods of materials.
h. Market information about the alternative price of materials in a market.

5.3. PRODUCTS AND SERVICES

The first product that serves the social value of the materials in a building is the CO_2 balance of a building. This product provides the sum of all CO_2 savings that are realized through the reuse of materials in a building. The CO_2 balance of a building combines the following elements, namely:

a. The size of each specific material in a building.
b. The ability to remove the material undamaged.
c. The "embedded Co_2" in the realization of new equal material at a standard weight.
d. Multiplying the actual weight of the materials by the "embedded Co_2" for each material.
e. The summation of all multiplications of all materials for the registered (in blockchain) owner in CO_2 saved in alternative use.
f. The market value of this Co_2 saving by multiplying the amount of Co_2 saved by the trading price of Co_2 rights, in accordance with the European Trading System of Co_2. (See eex.com; price of Co_2 rights as of 1 October 2022 = € 64.50)

The second product that serves the social value of the materials in a building is the materials balance of a building. This product provides the sum of all direct market values of the materials in an alternative use, such as can be obtained in a marketplace.

The Materials Balance of a building combines the following elements, namely:

a. The size of each specific material in a building
b. The ability to remove the material undamaged
c. The price of a material in a reusable materials market
d. Multiplying the actual weight of the materials by the market price for each material in euros
e. The summation of all multiplications of all materials for the registered (in the blockchain) owner in euros.

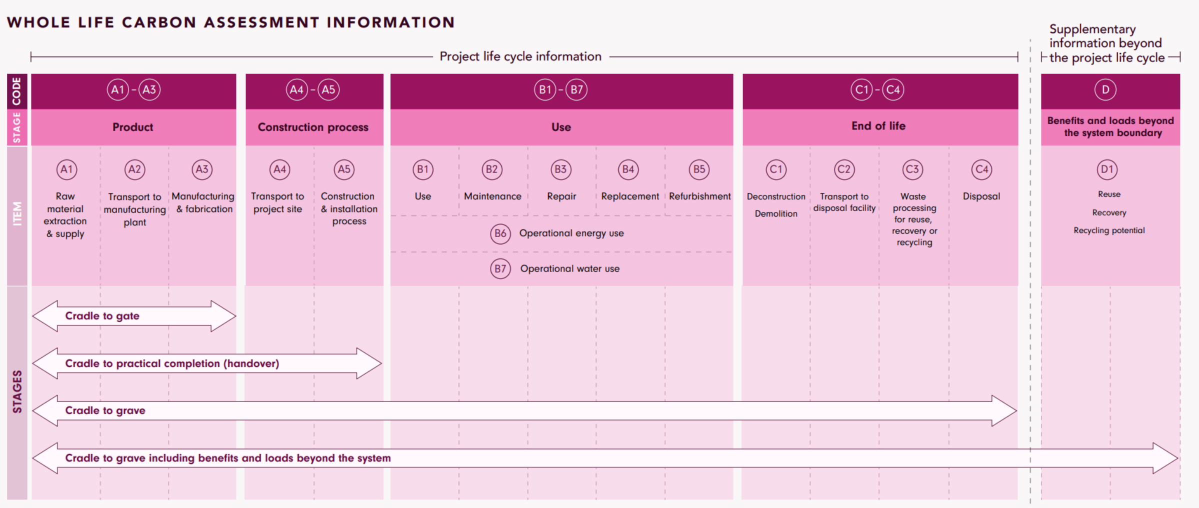
The third product that serves the social value of the materials in a building is the Social Materials Balance of a building. This consists of the sum of the CO2 balance and the materials balance of the building.

5.4. TECHNIQUES, TEMPLATES AND TOOLS

Templates are available within the Digital Materials Database, with which the calculations of the value of the products can be implemented. These calculations are based on the inventoried materials. Within the templates, all the basic data mentioned in paragraph 5.3. being filled in. The calculations can also be done in an Excel form, if the correct basic data is also available.

The embodied CO2 savings can be collected using different databases and reflect the following components for each material, as shown in the figure below:

Figure 1: WLC assessment modules as per BS EN 15978



One of these databases is the ICE database, built by the University of Bath in the United Kingdom. The Co2 calculations linked to the RBIM model, and the Digital Materials Database, use the ICE database. The calculation of the embodied environmental value assessed by RBIM is based in part on the assessment of the effort required to restore material and the repair effort required for its reuse. The Environmental Embodied value reflects the possible avoidance of CO2 emissions, waste, and energy, as well as potential material reuse.

In France, when calculating the CO2 savings for an old building, the LCA methodology established by the French government using the INIES database and the FDES is used. The CO2 savings are estimated to be equal to the CO2 emissions of a new product that we would have to buy if the material could not have been reused. A methodology (for Bordeaux Metropole) has also been developed by Nobatek to evaluate the effects of reuse approaches.

5.5. RESULTS

The result of the social valuation of a material is the representation of the actual value of a registered material in a digital materials database, which is also provided with a property right by means of a blockchain registration. The sum of the different property rights of materials in a building can be summarized in the materials balance of a building. If the CO2 value of the saved CO2 emissions is also added to this, the sum of this materials and CO2 balance forms the Social Materials Balance of a building.

5.6. QUALITY FACTORS

The calculations of the Social Value of the materials in a building are based on a transparent quality of the materials. However, this can lead to problems in practice, for example because of the presence of toxicity in certain materials. Then materials cannot be used as an alternative, even though they can be detached.

Another factor that influences the social value of materials is the presence of a market for reusable materials. Markets for reusable materials currently depend on the access of buyers and suppliers in a certain geographic region to this market, as well as on the transparent quality of the materials requested and offered. The more transparent the quality, the more buyers and sellers will value this market, which means that the value of new and reusable materials of a specific type will approach each other.

The prices of reusable materials in a building in a market are the product of both the intrinsic value of these materials, and the processing and handling costs of these materials to give them an alternative use. In economic terms, the value of a reusable material in a building will be lower than the value of a freely available material on a market, because in the latter the various handling costs are also included in the market price.

However, if the CO2 saved through reuse can be included in the pricing of reusable materials, this will increase the value of the materials in a building. If the Co2 value of a material is equal to the handling costs of a material to make it freely usable again in an alternative use, the market value of recyclable materials can be equated to the market value of primary materials, such as in a public marketplace (wholesaler for building materials).

For the time being, the saved Co2 cannot be converted directly into euros through reuse. However, calculations can be made, as if this were also possible. In addition, research was requested into the extent of the handling costs when dismantling materials, so that they are reusable with the desired quality. Research into the purchase prices of reusable materials by "harvesters" of building materials is another key component, which amounts to the quality of prices in markets for reusable materials in buildings.

5.7. Process Activities

When making a social valuation of the materials in a real estate object, the following process activities are discussed:

a. From chapter 3: inventory of the materials in a building, including properties, removability, and toxicity.

- Use RBIM output to work out the most desirable reuse options for a given project's circularity performance objective
- Use the Digital Materials Database to estimate the "embodied" CO2 of the deconstructed and reused products.

b. Choose an "embodied carbon emission" standard, as described in section 4 in this chapter.

- Compare values with the objective of the project.
- Environmental criteria can be quantities of products from the existing building reused and/or recycled, reduction of waste, avoided new products, reduction of transport, avoided Kg CO2 emissions.
- Use existing LCA tools (ex SimaPro), and/or tools proposed by marketplaces (ex Cycle-Up), and/or DDC tools (RBIM, Cirdax).

c. Collecting and recording the "embodied carbon emissions" of a material.
d. Collecting and recording the market prices of Co2 emissions (eex.com).
e. Collecting and registering the CO2 emission value in euros on the market for tradable emission rights.
f. Making the sums of materials, embedded carbon emissions and market prices in a carbon emissions balance, materials balance, and social materials balance.

5.8. Questions and Answers

The following questions have been raised in projects on this subject. Every question has an answer.

Is Co2 saving through reuse of materials a strategic objective of your organization?
Respondent 1: Yes.
Respondent 2: Between 2015 and 2030 we want to save 50% CO2. Reuse is therefore a particularly effective way to achieve our goal.
Respondent 3: Yes, we want to reduce our CO2 emissions and reuse is therefore a particularly effective way to achieve our goal.

Which measure for CO2 savings by reusing materials do you use now?
Respondent 1: The design team makes the calculation.
Respondent 2: Assessment with the DGNB approach.
Respondent 3: This is done as determined when drawing up the demolition inventory (which is mandatory for a Belgian permit application).
Respondent 4: External partners do the calculation.
Respondent 5: The CO2 savings are calculated using the LCA methodology drawn up by the French government. That is why we use the INIES database and FDES. This method is mandatory for all new buildings. When we calculated the C02 savings for an old building, we use the same methodology. The CO2 savings are estimated to be equal to the CO2 emissions of a new product that we would have to buy if the material could not have been reused.

Q: Reducing the amount of plastic packaging can limit supply and choice. This can potentially have a knock-on effect if products are damaged by improper packaging, resulting in more waste.
Answer: Specify manufacturers with packaging take-back services.

5.9. COMMENT

The following comments can be added about this chapter.

1. The Environmental Performance of Buildings

When designing and realizing a building, the Environmental Performance of Buildings (MPG) must be calculated. The civil engineering sector uses the Environmental Cost Indicator (MKI) for this. The MPG and MKI are based on the Environmental Performance of Buildings Assessment Method and the associated National Environmental Database (NMD) with the environmental performance of products.
The determination method provides that materials to be reused must be taken into consideration. Model-based rules have been included for this purpose. However, there are several points to consider when calculating the environmental performance of the structure. These also apply within certain margins when preparing frequently used products to be reused:
a. The original producer is unknown. It is complex to relate materials released from demolition to the 'initial or most representative product in the NMD', which is the starting point for the Determination Method.
b. There is a lot of variation in numbers and amounts of materials that are released. In the case of small series or individual products released from demolition, it is complex and expensive for an individual demolition contractor to perform the calculation of the score.
c. Each product to be reused is unique and there are no recipes for making an LCA analysis. Many different flows are released from a demolition work. An average job quickly involves forty varied materials, for which a calculation would have to be conducted.

The above arguments stem from the assumption that the environmental value of materials stems from the history of these materials. However, that is incorrect, because according to conventional economic theory these are “sunk costs.” Sunk costs are not relevant to a cost-benefit analysis, as advocated in this handbook. However, it does concern the production of new materials, which is prevented by means of the reuse of materials. This involves opportunity costs of the trade-off between the use of existing or new materials, or in other words, the disappearance of a material and the necessary new production, versus the reuse of materials, including the costs of processing and repair.

2. Other social values

In the various British projects on reducing the use of materials and thus also reducing CO2 emissions, many other social values are also discussed, which can be included in a social cost-benefit analysis. These are not all easy to quantify, as is the case for CO2 savings, but they can be included in a social cost-benefit analysis, so that their value is also visible.

This concerns the following examples:

1. Circular principles have contributed to numerous sustainability certifications and accreditations such as BREEAM and WELL.
2. Many of the case studies were conducted as pilot projects to inform clients' own sustainability strategies.
3. Access to financing benefits only available for projects with explicit sustainability measures and ambitions.
4. Value of preserving the historic structure and character of buildings.
5. Job creation (e.g., pop-up factories for refurbishing and processing reclaimed materials), measured by the number of jobs created.
6. Reduced air pollution (PM 10, PM2.5) and local congestion, measured by total savings on mileage because of reduced transport emissions from less required materials/transport.
7. Training opportunities for staff or tenants.
8. Social value by sharing material with charities and schools.
9. Marketing benefits for developers who want to reuse buildings in the future because of the CO2 costs of new construction.
10. Ability for residential buildings to accommodate changing family sizes and structures because of reconfiguration.
11. Longevity can mean that a building is less likely to be demolished after 20 or 30 years due to changing tastes, which can increase the social acceptance of the community.
12. Increased safety on site through prefabricated components that allow easier installation.
13. Support from local suppliers.
14. Increased health and safety of the manufacturing and demolition process and better community relations.
15. Low-impact materials can contribute to green rating schemes and increase health and well-being.
16. Pleasant spaces for residents designed with well-being in mind.
17. Using low-impact materials can lead to benefits for better health and well-being.

5.10. REFERENCES

Scientific references

a. Embedded Co2: The University of Bath's ICE Database - https://circularecology.com/embodied-carbon-footprint-database.html

References within projects

The stones in Ettelbrück station have already been donated to INPA (Institut National du Patrimoine et de l'Architecture). The INPA wants to reuse the special bricks to rebuild the same station in a different location. The stones come from a quarry that has been closed for a long time, making the stones very scarce and therefore of great historical value. Including the savings in CO2 (including value) by reusing these bricks.

6 Inventory of the costs of services in the event of the demolition of a building

6.1. Introduction

Certain costs will be incurred for every real estate object that is provided with an alternative destination. This also applies to the costs of services during the demolition of deconstruction of a building. In this Handbook, the cost of providing services for the demolition of a building, or the alternative use of the materials in a building, is separated from the value of the materials. In this way, both the costs and benefits of the demolition of a building can be implemented in a transparent and appropriate manner, and costs and benefits are not necessarily mixed with each other.

Demolition of a building also ensures that a building, the land on which the building stands, and the materials in the building can be given an alternative destination. The added value of demolition and the associated costs must therefore be considered in the light of both the alternative revenue from services realized by a new building, the change in the value of the land because of the alternative use of the land after the demolition of the original building, as the value of the materials in an alternative use.

This also means that the costs of demolition cannot be directly attributed to one of the possible proceeds of demolition, but that this must be a weighted average, depending on the choice of cost allocation. A topic that will be discussed in the next chapter of the handbook. This chapter is about mapping out the various costs associated with demolition, both in a traditional way and in a sustainable way aimed at reusing available materials. In this way, the alternatives are also mapped out and they can form part of consideration issues in actual decision-making.

6.2. Input

The following information is required to determine the costs of sustainable demolition:

a. The data of the building in terms of size, construction, and all other aspects of a building that can be read from drawings of the building.
b. The inventory of the materials in the building
c. The removability of the materials in the building
d. The types and extent of a demolition contractor's services in relation to the stripping, removal, dismantling and demolition of the various elements and materials in a building, as well as the preparation thereof.
e. The planning costs of removing the materials in terms of transportation and storage.

6.3. Products and services

The products and services that serve to calculate the costs of demolition are:

a. A methodological set-up of costs applied to the cost of demolishing a building.
b. The different cost prices of tools, machines, aids, and workforce.

6.4. Techniques, Templates and Tools

Primarily, the techniques are based on a methodology with which the various costs of demolition are mapped out. For example, arising from a demolition plan, in accordance with the requirements in a particular country. For the Netherlands, we are talking about BRL SVMS-007 and the Circular Demolition Project Verification Scheme (VCS). Templates can also be used to compare the costs of traditional demolition and sustainable demolition, so that the marginal costs of demolition become visible based on the adjacent alternative to sustainable demolition, namely a traditional method of demolition. These marginal costs can therefore be compared with the marginal revenues of sustainable demolition, as presented in Chapter 2.

The templates and instruments for determining the costs of demolition are often included in the products and services, which provide insight into the costs of demolition. Examples of demolition companies or in its simplest form an applied Excel form can serve here.

6.5. Results

The result of determining the costs of sustainable demolition is a quantitative interpretation of the various aspects of sustainable demolition of a building, so that they can be placed in an assessment framework. This assessment framework is discussed in Chapter 7 (Decision-making).

6.6. Quality Factors

The most important quality factor in this chapter is the correct use of cost calculations and cost allocations using business methodologies that are appropriate within the standards for controller practices. Given that the correct information has been provided with inventories.

6.7. Process Activities

When making an inventory of the costs of services for the demolition of a building, the following process activities are discussed:

a. Choosing a specific cost method.
b. Filling in this cost method with the data already collected from inventory or from previous projects.
c. Supplementing missing data based on a request for this data from suppliers in the field of demolition.
d. Preparing the cost overviews based on this methodology.

6.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Every question has an answer

- There are no questions and answers for this chapter yet.

6.9. COMMENTARY

The following comments can be added about this chapter.

1. The BRL SVMS-007 and the Verification Scheme Circular Demolition Project (VCS) in the Netherlands prescribe that a plan is drawn up for the demolition process. The materials released are inventoried during the demolition process. It is assessed whether the released materials meet the specifications. After the demolition, according to the VCS, a substance account is drawn up. A certifying body verifies this substance accountability. This makes it possible to demonstrate how much material of which quality has been released from a project. To reduce time and costs in the future, it helps if there is more insight into the history, quality, and removability of products during demolition. This can be done by drawing up a materials passport for a structure and the products used (see also CB'23 Passports Guide for Construction).

2. Quality assurance of products to be reused is necessary to remove uncertainties or unfamiliarity with, for example, designers, contractors, quality assurance officers or competent authorities, and to demonstrate that the requirements are met in a new application. A demolition contractor must first conduct a quality assessment. The assessment method is in line with the process, the material concerned and the desired application. The first quality assessment must take place while the building element is in use in the 'old' situation. The quality can be demonstrated during the use phase.

6.10. REFERENCES

Scientific references

There are no scientific references included with this chapter yet.

References within projects

No references to projects have yet been included in this chapter.

7. Decision Making

7.1. Introduction

The different qualitative costs and benefits associated with the alternative use of materials can be added together after the various quantitative and financial values of the materials have been entered, so that there is a conclusive cost-benefit analysis. For this it is also necessary that the various costs and benefits are also correctly compared in time, including the correct discount rate to make future benefits and costs comparable with costs and benefits that occur in the present.

In addition, it is important to compare all the costs of deconstruction with all the benefits of deconstruction, because construction work not only contributes to the alternative yield of the materials, but also to clearing the land on which a building stands for the benefit of the alternative use of this land, and also to the added value of the alternative use of the building in terms of residential, office, retail and other services.

The final sums of costs and benefits then form the basis of a decision on how the materials in a building or the building itself will be provided with an alternative destination.

7.2. Input

The following input is required to decide about the method of demolition:

a. The economic benefits of reusing materials, land, and function of a building (chapter 5)
b. The social benefits of reusing materials, soil, and function of a building (chapter 5)
c. The costs of demolition (chapter 6) according to the chosen cost method.
d. A discount rate for discounting future costs and benefits.
e. A methodology for allocating costs to benefits and making an integral cost-benefit analysis.
f. Business economics information about the costs and benefits of traditional demolition of a building.
g. The Digital Materials Database stores information about the ownership of the materials, supported by the blockchain module and the (technical) possibility to reuse materials in the building, supported by the Reversable BIM module. The inventory process for entering information into the Digital Materials Database uses information provided by digital or 3D scanning, saving inventory time compared to manual inventories. The Digital Materials Database provides information that can be used for cost-benefit analyses.
h. The DDC platform and its tools can be used to identify the potential of the existing building and potential scenarios associated with it.

7.3. PRODUCTS AND SERVICES

The final product in this chapter is an integral cost-benefit analysis about the method of demolishing a building, so that a manager can decide. The product is in the form of a decision document.

7.4. TECHNIQUES, TEMPLATES AND TOOLS

To make an integral cost-benefit analysis for decision-making, the analyzed costs and benefits can contribute to decision-making in two ways. The first compares all (integral) costs and benefits of a building in the field of sustainable demolition or deconstruction and enables a manager to decide based on this comparison of costs and benefits.

The second technique is based on a marginal cost-benefit analysis. This means that a manager's decision is made based on a comparison of the costs and benefits of a traditional demolition method with the additional costs and benefits of sustainable deconstruction. With this second technique, it is important that business economic information related to previous traditional demolition projects is available and usable for this marginal cost-benefit analysis.

The methodology for cost-benefit analyzes for Circular Demolition can therefore be based on the following two equations, which distinguish between classic demolition and circular deconstruction.

The equations are written in terms of costs and benefits:
1. $K = O + Sk + Dk - Mk$
2. $C = E + I + V + Dc + R - Mc$

The letters stand for the following aspects of the demolition and/or dismantling process:
K = The costs and benefits of the classic way of demolition
C = The costs and benefits of the circular deconstruction method
O = the organizational costs of the demolition and/or deconstruction process
Sk = the cost of the classic services of a demolition company
Dk = the costs for removing and depositing the materials after demolition
Mk = the yields of materials from a classic demolition process
I = the costs of inventory and recording of the materials in a building with a materials passport
Sc = the costs of the circular services of a demolition company
Dc = the cost of disposing, depositing materials that no longer have value and storing for reuse the materials that still have value.
R = the cost of processing the materials released from a building into new materials to be used
Mc = the yields of materials from a circular deconstruction process.

The purpose of the analysis is to determine exactly what the above variables embody in each situation. And which aspects can ensure that the extra efforts in a circular process also led to extra benefits, so that the K > C, i.e., to the situation in which the costs of the classic demolition process are higher than the method of circular deconstruction.

Or described the other way around, when a circular deconstruction process is of added value, on which an organization can determine its strategy in the field of building, land, and materials. Once the strategy is clear, it is also easier to initiate long-term investments in circular deconstruction and to deploy the associated tools, such as the Digital Materials Database.
The methodological explanation is therefore a basic framework within which the use of all Digital Deconstruction tools can be placed, because without a clear goal the added value of the Digital Deconstruction tools and all its functionalities cannot be evaluated. You do not know what you are evaluating it for.

7.5. RESULTS

The result of the work in this chapter is the decision to demolish a building traditionally or sustainably.

To simplify the analysis and get this result, you can assume that in the classic scenario it is only about costs and that the material yield can be set to 0. In addition, you can assume that the organizational costs of both processes are the same, even if the lack of knowledge about circular demolition/dismantling temporarily causes differences in these organizational costs.

In a break-even analysis, the combination of equations 1 and 2 then looks like this:
3. $Sk + Dk = I + Sc + Dc + R - Mc$

In other words
4. $Mc = I + (Sc-Sk) + (Dc - Dk + R)$

Equation 4 states that the material yields are equal to the costs of inventory I, the extra costs for service provision by the deconstruction company and the extra costs for depositing, processing, and storing the materials. The task now is to take a closer look at these costs and benefits. In a marginal cost-benefit analysis we would say that:

5. $dMc = dI + d(Sc-Sk) + d(Dc-Dk+R)$

This means that the change in the income from circular deconstruction must be equal to the (new) costs of inventory, the change in the costs of the deconstruction company's services and the change in the costs of processing, depositing and storage of the materials. In this way, costs and choices can also be linked, because in this way the opportunity costs and benefits can be weighed against each other.

7.6. QUALITY FACTORS

The availability, completeness, and reliability of all business economic information about a building and the materials in a building is a key factor when deciding. Deciding in the event of incomplete information is a norm rather than an exception. The completer and more dependable the business economic information about the costs and benefits for the decision on sustainable deconstruction, the preferable a decision based on an integral cost-benefit analysis. As the quality of information declines, it is better to focus on a marginal cost-benefit analysis and inferred decision.

Another important quality factor concerns the time available to perform all activities, as well as the time factor in general. By the latter we mean that costs and benefits can only be properly compared if they relate to the same period, so that costs in the present do not have to be compared with revenues in the future.

The quality factor of time concerns the possibility to inventory suitable materials, as well as to find a buyer for these materials. It is precisely by making an early inventory of materials, in accordance with the provisions of chapter 3, that the transparency of the quality and availability of materials becomes clear. A demolition or dismantling company then has the preparation time and options ready to remove the materials from a building without much damage to materials. If this time is not available, the quality of the demolition process is much lower and the damage to materials is much higher.

Second, the quality factor of time relates to finding a buyer. The more time available, the more matching options can be organized between the supplier and requester of secondary materials. How much time is ideal depends on the buyer's network of materials at the property owner or the demolition company or is related to an improved organization of buyers and suppliers, for example based on a digital marketplace (see Chapter 12). The less time available for matching, the lower the returns will be in a social cost-benefit analysis.

The quality of time can be improved by investing in advance in information about the materials in a building. This is done through inventory work or through investments in the environment in which suppliers and buyers meet. In practical terms, we are talking about a digital marketplace, where you can start trading if the materials are still in the building. A trade based on the property rights of the materials in a building.

A final dimension related to time in a cost-benefit analysis concerns the discount rate used, with which future costs and benefits are settled into the present, i.e., discounted. The advice for this interest or discount rate is in line with the discount rate for social cost-benefit analysis. In the Netherlands this is currently 2.25%.

7.7. PROCESS ACTIVITIES

In the actual decision-making process about the alternative use of a building and the materials in this building, the following process activities are discussed:

a. Realizing the (social) costs and benefits.

- Use all data collected during the inventory of the materials, including the resulting transactions.
- Estimate the possible reduction in transport costs.
- Don't forget all the secondary costs of the reuse approach (resolute support team, insurance, product testing, storage, ...)
- If elements are reused by the same building owner (same location or not), consider charting the savings on new products as an example of a cost-benefit analysis or part of it
- Assess all indicators defined at the start of the approach. Embodied Co2, waste reduction, number of recycled elements, reduction of new products/resources for other projects...
- Use common LCA tools, homemade tools, tools from marketplaces (ex Cycle-UP), DDC tools.
- Use RBIM tables to estimate the ultimate effects of material reuse and define which products have been reused and recycled (low-value and high-value).
- Use the Digital Materials Database to estimate the ultimate impact and determine which products have been reused and recycled.
- Use a tender procedure for the selected demolition companies that can help to collect all costs and benefits (see chapter 8 for details of the tender)

b. Recalculate future costs and benefits to their present value.
c. Attributing the right costs and benefits to the decision to be made.
d. An assessment of the completeness and quality of costs and benefits.
e. Choosing a decision model.

- Use cost-benefit analysis on GreenFlex's DDC platform and economic assessment tool.

f. Make the decision.

7.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Every question has an answer.

Question: The VAT on materials for renovation projects is higher than for new construction projects.
Answer: The cost difference can be reduced by reusing existing structural elements to reduce construction time and amount of materials. The thorough renovation of the Bartlett School of Architecture resulted in total cost savings.

Question: Since minimizing the impact and wastage of materials can deviate from the standard for building, there may be reduced availability of low carbon materials. Materials

that may have a higher cost (especially when combined with a disassembly design) and longer program implications.
Answer: Collaborating earlier with manufacturers and contractors makes it easier to understand the availability and opportunities for gentle impact and waste materials that do not contribute to cost and program. Alternative options are also often not explored because tenders are discussed too late, and the lack of time causes certain matching options to expire and thus to missing revenue. Early involvement was key to the success of The Forge and The Entopia Building projects. The Enterprise Center was an experimental project to evaluate low-impact materials, but the last price of the materials was not much different from previous alternatives.

7.9. COMMENTARY

The following comments can be added about this chapter.

- There are no comments available yet.

7.10. REFERENCES

Scientific references

Any choice in a cost-benefit analysis is based on an opportunity cost analysis (i.e., a (minor) cost-benefit analysis). This is in line with the foundations of economics, which hold that value can only be attributed to those things that are scarce and can be used alternatively considering people's needs and behavior (Robbins 1962). Lionel Robbins states:

"The economist studies the disposal of scarce resources. He is interested in how different degrees of scarcity of different goods give rise to different valuation ratios between them, and he is interested in how changes in ends or changes in resources—of the demand side or supply side influence these relationships. Economics is the science that studies human behavior as a relationship between ends and scarce resources that have alternative uses."

Materials in or for buildings are alternately applicable and scarce. That is why choices and (alternative) costs are always linked. Where no choice can be made about the alternative use, such as with toxic substances or materials, a material also has no value. Nobel laureate James Buchanan quotes Frank H. Knight on the principle surrounding these types of costs:

"The idea of opportunity cost is central. The cost of any alternative (simple or complex) chosen is the alternative that must be given up; where there is no alternative to a particular experience, no choice, there is no economic problem, and costs have no meaning. Economic costs thus consist of forgoing an 'other' use of a particular resource or resource capacity to secure the benefit of the use for which they are intended. The only general theory of cost that can be maintained, will be that of opportunity cost."

Lionel Robbins, An Essay on the Nature and Significance of Economic Science, London 1962

JM Buchanan, Cost and Choice, Chicago, 1969

References within projects

1. Below are many examples of financial results from projects mentioned by the British Green Council in the report "Insights on how circular economy principles can impact carbon and value."

Reuse the substructure and superstructure of a building

1. Triton Square: Total project had a saving of 15-18.5% compared to new construction, partly thanks to the reuse of substructure and superstructure and materials.
2. The Entopia Building: Project cost estimated to increase 4-8% over a standard Part L retrofit, but this was an experimental pilot project to minimize carbon emissions.
3. Timber Square: By preserving the building, there was a floor slab with a higher value than normal.

Facade reuse

1. Triton Square: Savings of £2 million (10-20% cheaper than new facade) partly due to time savings.
2. The Burrell Collection: £100-500k savings from retaining aluminum facade.
3. 80 Charlotte Street: Reuse of existing brick facade; some additional testing and modeling costs compared to purchasing a new facade project were within budget and on time.

Material and product reuse, e.g., glass frames, brick, steel

1. The preliminary work by Cleveland Steel & Tubes and the UKGBC CE Forum points to a 30-40% profit per tonne at current market prices of recycled or reclaimed steel compared to virgin steel (32-44% savings), assuming the steel is located in a building owned by the client; buying recycled stock from stock is slightly more expensive, but still saves you 10-20%.
2. JLL Office Fit-out: Savings of over £40,000 achieved by giving the furniture pack a second life compared to equivalent modern furniture.
3. Cambridge Avenue: Re-use of the lift saved £5000, and the reuse of materials provides a 25% cost reduction in materials and products, but due to the complexity of the project this did not result in an overall cost saving compared to new construction.

Higher rental values to demonstrate to tenants the improved usability of the space

1. Triton Square: a significantly faster rental time than expected for a property of its kind, although this is not only due to the use of circular principles.
2. Canal Reach: The design allows great flexibility with how many tenants can occupy the building due to the large floor slab. The building can be used as one building, split into two buildings or have up to 8 tenants per floor.

Flexibility can create greater value mixed-use buildings

1. The Forge: Floor-to-ceiling height and reversible components allow for future change of use.
2. 80 Charlotte Street: Steel base structure and pre-cast planks enable future use.
3. The Bartlett School of Architecture: Communal areas are designed to be flexible with some walls that can pivot or be lightweight so that future layout configurations can be simplified.

Income from resale of second-hand equipment (for example, steel from a portal frame)

1. Building as a material bank approach: material prices are increasing, future owners have value stored in the building components (value in the building itself, not just the land).

Future repair/maintenance/replacement cycle costs lower compared to business-as-usual

1. This can save costs for the developer/client of the building if they want to retain ownership of the building, or the future owner/user if they have some direct control over the use phase of a building.
2. Applying passive design strategies can provide resilience, as well as metrics to cope with future climate scenarios.

Lower future furnishing costs if the products and materials can be reorganized for different purposes

1. Designing with flexibility in mind can ensure that the materials and products are suitable for future use or reused by users in other buildings.

Where an external or internal carbon price is used, cost savings can be recognized by minimizing impact and waste

1. Magnitude 314: Lower compensation costs to meet UKGBC net zero framework in construction.
2. Holbein Gardens: The incorporation of circular principles is expected to reduce the cost of carbon offsetting once completed.

Waste design has close ties to optimization design, as minimalist designs lend themselves to greater flexibility and adaptability in the future. This lowers initial construction costs while also providing a marketing opportunity for increased use of space.

1. Canal Reach: waste designed by having a visible structure, reducing the need for short life in rented areas; this had minimal/no impact on costs.

2. The Croix Luzet project near Lyon

• Demolition of a 100-unit building along the highway (Croix Luzet):
• Inventory of materials: 2600 m² solid oak parquet floor, cast iron radiators, doors, cellar, roof railings, crinoline ladders, concrete
• After research, disposal is estimated to be more expensive than reuse
• 3500 tons of crushed concrete to redo the concrete, i.e., 50%. To be completed for the rest or lost due to a lack of coordination in the upstream chain.
• Financial balance at + €50k on a total budget of €1.5 million
• Rehabilitation of student, elderly, and ESS housing in Villeurbanne (IUFM):
• Set up in situ reuse (tiles, terrazzo, windows) and ex situ (walkways of metal that become corridors, for example)

Croix Luzet learns that financial results increase with sustainable demolition due to:
• Putting recycling companies at the heart of the design and by working with objectives of results and not with available resources and capabilities.
• Encourage experimentation and drive change in classical ways of working.

• Enable the product to be reused at a lower cost through the development of reprocessing and repair centers, for example for sanding and varnishing parquet, sanding subsequently varnished radiators, stripped toilets, etc.
• Put residents at the center of the design or rehabilitation of their habitat. In this way they get used to a new destination of, for example, their own furniture, and they start reusing part of the waste from the project.

8. DEMOLITION PREPARATION

8.1. INTRODUCTION

This chapter describes the various preparations that must be made by a demolition or dismantling company if the execution of the deconstruction is to lead to a positive result for all stakeholders in a project. That is, the delivery of those reusable materials that the owner of the property wishes to obtain based on the registration of these materials in the digital materials database and the added value thereto. We start from the decision to demolish a building in a sustainable manner and to use the materials from the building in an alternative way. This means to sell to a third party, or to reuse it yourself for a new building or the renovation of an existing building.

The data relating to the value of materials from a building determines which services are required from a demolition company in a circular demolition process. The materials inventory gives shape to the specifications in a quantitative sense. In other words, which materials should be removed from the building and how. The property owner also indicates the value of materials that the demolition company must provide after its services, so that waste and loss of value of materials is prevented as much as possible. The timely material inventory also gives the space in time to organize the work in the best way, including finding the buyers of the materials at the highest possible value.

For every project or pilot, it is important to design the specifications for the contract to the demolition company in such a way that it is clearly indicated how the demolition contractor should manage the materials and how he should deliver the materials, or to the desired location for the materials. to bring. This can be a depot for low-grade processing, or a depot of the property owner or the party that has already purchased these materials, or a processor for high-quality processing (upcycling) considering the wishes of inexperienced users.

In the direction of a demolition company, a distinction must always be made in circular deconstruction in terms of service and in terms of value of the materials. In a classic way of demolition, everything is lumped together, so that a lot of information about the materials is lost. Information that can give materials a lot of value if the demolition work is done correctly. Therefore, ideally, a demolition company is only asked about their services and separated them from the revenues of the materials and the costs associated with storing or processing materials.

In this way, an important insight is gained into the cost-benefit analysis of each material for certain parts of the building, as well as the different costs of services associated with the "harvesting" of each material. It also becomes visible which costs can be avoided in the future if parts of a building can be dismantled due to the choices made when building the building.

This chapter examines the various activities step-by-step, as well as the risks associated with the activities and the necessary quality.

8.2. INPUT

The demolition preparation has the following input variables:
a. The decision to sustainably demolish a building (chapter 7)
b. The inventory and registration of the materials in the digital materials database (chapter 3)
c. The RBIM results regarding deconstruction steps, type and number of connections and their locations as part of tender documentation (chapter 3).
d. The availability of the 3D reversibility data and 3D viewer in the project documentation (chapter 3).
e. An overview of the degree of removability of the materials in the building (chapter 3). Use these results stating:
(i) the number of disassembly operations per product,
(ii) the number of disassembly steps,
(iii) the number of physical relationships per product/material
(iv) the type and number of direct and indirect connections made during assembly and after assembly of the products to develop disassembly strategy
f. The social value of the materials in the building (chapter 5).
g. Knowledge of these materials and value among employees.
h. The available people, machines, aids, tools, and methods.

In some cases, the following inputs are ideal, but not mandatory, when preparing for the demolition process:

- Disassembly testing allows to identify the best method of deconstruction to maintain product integrity. Try to observe the disassembly potential during a visit, or the later visit organized after the products become available.
- Organize a specific visit with the demolition company. They can look and advise expertly.
- For true deconstruction of previous tests, target products that do not require heavy machinery (unless these machines are already present).
- Drawing up a contract for the disassembly tests.
- The time for disassembly testing should be provided in the project schedule.
- If residual performance is unknown and critical (or required by users or a control agency), provide required verification testing. Consult existing guides (e.g., French FBE guides on a range of products, which describe the verification protocols), consult product standards (national and/or European) which describe the tests required for new products, speak to the control agency about characteristics required and needed tests.
- Minimize the number of tests (= costs) and take the estimated performance into account where possible.
- Estimate the cost to contact experienced local labs, manufacturers, or actors.
- Sometimes evaluates at universities are accessible. This saves on costs.
- Run tests on representative samples.
- In all cases, think about insurance issues. Validate with the design team, with the control agency, with the assurance that all necessary necessities are available.

8.3. PRODUCTS AND SERVICES

When preparing for the demolition, the work must be arranged in such a way that the materials are delivered, as desired by the client, at the value in society for this customer. This is based on the analysis of the available materials in a building, the degree of releasability of these materials and the value of these materials. This means that the services to be provided by a demolition contractor are aimed at delivering those materials with a certain value and that he is in fact also liable for this. The delivery of these values should be central to the contract between the client and the demolition company, whereby points of attention such as damage, risks, force majeure, and all associated elements that are necessary to guarantee the value for the customer are essential elements. Such an agreement is therefore an important product. A difficult product when this comes up for the first time.

A second important activity for the sustainable removal of materials concerns the preparation of people, machines, tools, and other aids to be deployed in the demolition of a building. A preparation that is aimed at that combination of deployment of resources, that damage and other forms of loss of value can be prevented with different construction forms of a building. And where the value of the customer is central.

Derived from this preparation of work, activities are then discussed that are operational in nature, such as setting up the work area, the ongoing risk analyzes about hazardous situations for people and machines, the use of electrical and motor aids, the logistic flows related to materials in the workplace and the disposal of these materials.

It has already been indicated in chapter 7 that organizing the buyers of the materials in a timely manner and thus also the disposal of the materials is an important yield-enhancing activity. Therefore, also start by organizing well at the end of the process, because it is precisely in this link that the most added value is created in a social cost-benefit analysis about Circular Deconstruction.

8.4. TECHNIQUES, TEMPLATES AND TOOLS

Sustainable deconstruction focuses on value creation for the customer in the form of maximum reusable valuable materials. Techniques from the world of optimizing production processes, such as the Lean philosophy, as originally developed by Toyota, can play a key role in this. Using the Lean philosophy in demolition is new but can be an important service quality tool for the entire sector.

If a tender is used to organize the collaboration between the property owner and the demolition company, the templates for this tender should focus on:
• the information about the building in the tender documents
• mentioning all elements related to the reuse approach in the tender: technical inventories, reuse objectives.
• the provision of a catalog/inventory of the possible elements for reuse.
• the organization of site visits.

• soliciting experienced building owners to share approved tender documents and contracts.
• the selection of experienced and strong references on the reuse approach.
• the selection of the company with the highest added value. Not with the lowest cost.
• collaborating with local teams. They know the local network better, construction sites come and go, eventually they will be more present during the project.
• choosing experienced companies with strong references in the field of deconstruction and reuse.
• the demand for the use of methodology, first ideas, etc. Information specific to the project.
• demand from companies for information on methods to deconstruct, store and transport key products.
• provide drawings of the elements that would be reused, provide a catalog of all elements integrated in the reuse approach.
• organizing visits.
• requiring companies to provide proof of insurance for the implementation of reuse solutions.
• being clear about the objectives (deconstruction actions, requirements for the quality of products after deconstruction, % damage, timing, responsibilities for storage and transport, etc.).
• the customers of the materials that are released.

8.5. Results

The result of the work for the preparation of the demolition of a building is an operational plan with activities that yield an agreed value of materials for the customer. Not primarily a clean site, but a combination of labour, resources, and method, which yields both a clean site and optimum value in alternatively applicable materials. Work for which the demolition company is remunerated in terms of its services, and no longer in the form of a combination of remuneration for services and its own proceeds from materials. The latter now belong to the owner of the building.

8.6. Quality Factors

The quality factors that are discussed in this part of the work are like the quality factors that are also discussed in production and/or planning companies in terms of their operational processes. It is important that use is made of a certain quality standard, or philosophy. An example of the first is working with ISO standards. An example of the second, which goes far beyond a standard, such as ISO alone, is the Lean philosophy.

8.7. PROCESS ACTIVITIES

During the preparation of the various deconstruction activities, the following process activities are discussed:

a. Establishing the goals of the deconstruction between the client (owner of the building) and contractor (demolition company).
b. Making an operational deconstruction plan aimed at optimizing the value for the customer, given the preconditions as agreed in the assignment.
c. Setting up the work area, making risk analyzes and making available the necessary capacities, machines, aids, and tools to conduct the deconstruction process.
d. Define a scenario to follow to allow flexibility.
e. Acknowledge these aspects with all stakeholders: timing, storage, costs, elements to be deconstructed and by whom and for what purpose, destination of deconstructed elements.
f. Use the Digital Deconstruction platform and Digital Deconstruction tools to identify the potential of the existing building and potential scenarios.
g. Use a building's digital reversibility to define design requirements for the design team and the required circularity profile of the building, as well as deconstruction and reuse requirements for the contractor.

8.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. An answer is provided for every question.

Do you request different quotes from the demolition company for a classic demolition method and a circular demolition method? If so, how do these quotes differ?
Respondent 1: Normally not. Prior to the tenders, we signal the willingness to apply a circular process. That is why we include this question in the tender documents and the quotation is drawn up based on these requirements.
Respondent 2: No. If circular demolition is requested, this is detailed in the tender document, and it is the only quotation that is requested
Respondent 3: So far: no. From now on, of course. We are thinking about how we can best provide this in our public tender documents.
Respondent 4: Normally not.
Respondent 5: Yes, the demolition company must estimate the cost difference between a demolition and a deconstruction. It depends on the materials, sometimes it is the same protocol, and sometimes it is much more complicated to deliver the material without damage. So, the quote may differ between the two methods.

Question: Local authorities may impose requirements on the preservation of a building's heritage elements, which may hinder improvements in energy or material efficiency.
Answer: Many local governments have declared climate emergencies and/or have set far-reaching carbon reduction targets. This can be referenced in addition to the potential carbon savings from replacing the heritage elements of the building. The Cambridge Municipality Conservation Team (Entopia Building) wanted to preserve the Georgian-style appearance of the windows, which would limit natural light and improve operational energy

efficiency. By demonstrating how the CO_2 savings would align with the municipality's science-based reduction targets, and how the windows could be changed while preserving the building's key heritage elements, a compromise could be reached.

Question: Unknown building elements can increase program time and costs.
Answer: Ensure that the program allows time for assessing the condition of materials before the project starts. The availability of passports ensures that these issues can be solved more easily in the future.

8.9. COMMENTARY

There are no comments to add yet.

8.10. REFERENCES

References within projects
The desire to supply the stones from the Ettelbrück station as individual products for reuse means that there is no question of a classic demolition process, but a dismantling of the building. As desired by the building owner, a quotation was made during the project phase for a classic method of demolishing the building, but later supplemented with quotations for a sustainable method of dismantling, as described in the tender documents. It concerns varied materials with different values, with each material generating its own cost-benefit analysis, whereby additional costs up front (inventory and analysis), the additional costs for disassembly (how large are these), are weighed against the additional returns of scarce materials. For the continuation of the pilot, an interview is planned with the demolition/dismantling company about the different efforts in a traditional demolition process and the activities that are conducted in a sustainable demolition process, including the differences in costs/benefits and different working methods. The demolition company will work with "gold (scarce stones)" and what this means for them. And how to deal with materials that are becoming increasingly scarce, and the effect on their way of working now and in the future.

9. THE EXECUTION OF THE DEMOLITION AND THE ASSURANCE OF THE VALUE OF THE MATERIALS.

9.1. INTRODUCTION

This chapter deals with the way in which the value of the materials can be safeguarded in an effective manner during demolition work. It describes various methods, techniques and procedures that should ensure that waste of materials and damage to materials are prevented, so that the value of materials remains as high as possible. And requirements of the property owner, who is liable for the delivery of the materials of a specified value to a purchaser of the reusable materials, can be met.

9.2. INPUT

a. The operational demolition plan.
b. Setting up the work area.
c. The availability of risk analyses.
d. The availability of capacity, machines, tools, and resources.
e. Knowledge of materials and the value of materials among employees.
f. Working methods and craftsmanship for sustainable demolition.
g. The use of instruments from the quality framework used by the demolition company, for example from the Lean philosophy.
h. The broad understanding among the demolition company and its employees of the concept of "value for the customer", the prevention of "damage and waste" and familiarity with the consequences of "liability".

9.3. PRODUCTS AND SERVICES

The demolition company provides the following services in the operational demolition process, following from the operational demolition plan:

a. Removing, stripping and/or dismantling stairs, frames, roof constructions, ceilings, floor finishes, wall finishes, roof finishes, installations, stone walls, separation walls and wooden beams.
b. Removing or demolishing the constructions of a building.
c. Separating the varied materials at the source
d. The removal of the various materials to the depots for these materials or to the reuser of the materials.

9.4. TECHNIQUES, TEMPLATES AND TOOLS

The techniques, templates and tools that are available for the execution of the demolition belong to the domain of the demolition companies themselves. This concerns working methods, tools, aids, machines, and trained people. And instruments aimed at avoiding damage, loss, and waste in the operational process, so that the value for the customer of the reusable materials is guaranteed. We will only talk about these techniques, templates, and tools in a general sense in this handbook. For the time being, we will leave the specific descriptions with the demolition companies themselves.

9.5. Results

The result of the demolition process is the "handing over" of the materials from a building to the owner of these materials, so that the materials can then also be used alternatively, in accordance with the agreed goal.

9.6. Quality Factors

The quality factors in the sustainable demolition process are strongly influenced by the standard that imposes the “customer value of the reusable materials.” Derived from this standard of quality, many common quality factors in a demolition company will still be addressed, such as those related to safety and working conditions. However, the focus in the various quality factors can change if the focus is not on a clean site, but on the interpretation of the optimum social value for the customer in a general sense. Depending on the development, vision and mission of a demolition company, quality thinking will undergo small or substantial changes, which step by step based on the development of employees' competences, evaluation of business processes, cases, kaizen workshops etc. to a process of continuous lead to development and improvement.

For the time being, we will only follow the general development in this handbook. The detailed application of quality is left to the demolition companies themselves.

9.7. Process Activities

During the execution of the demolition and the assurance of the various materials and their value, the following process activities are discussed:

a. Conducting the demolition work.
b. The design and support teams must strictly follow the deconstruction work, collect the documents, take pictures, live manage the recovery of deconstructed elements by targeted actors, report deconstructed, sold, stored elements.
c. Separating and disposing of the materials.
d. Continuously evaluate to make improvements to prevent damage, loss, or waste relative to customer value.

9.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Every question has an answer.

Question: Visual appearance of recycled materials can reduce a building's rental potential.
Answer: Find examples of repurposed assets or materials to highlight to customers and agents, and make sure they know the marketing potential of low carbon or circular properties. At the Entopia building, the client was initially hesitant about the reused raised access floor as a visible finish, but after seeing a similar example, they supported the installation of the floor.

9.9. COMMENTARY

The following comments can be added about this chapter.

1. If materials are not traded directly, the shadow price of the primary materials can alternatively be used to describe the value of the materials. In this case, given the price formation in local markets, multi-market averages will have to be prepared for the correct data.

9.10. REFERENCES

References within projects

The stones in Ettelbrück station have already been donated to INPA (Institut National du Patrimoine et de l'Architecture). The INPA wants to reuse the special bricks to rebuild the same station in a different location. The stones come from a quarry that has been closed for a long time, making the stones very scarce and therefore of great historical value. Including the savings in CO2 (including value) by reusing these bricks. For the continuation of the pilot, an interview is planned with the future owner of the stones, so that we can get an idea of the alternative value of the stones. We can also gain insight into the costs of repairing the reusable materials, as well as the costs of storage and wear and tear.

10. SECURING THE MATERIALS IN A DEPOT

10.1 INTRODUCTION

To be able to physically reuse materials, the detached and removed materials from a real estate object must be stored in a depot for the period that they will not be used or wait for reuse. This chapter describes the various aspects of securing materials in a depot, including reducing the costs that can be associated with keeping materials in a depot. The fastest way to reuse materials from a real estate object is directly from a building to a new building. However, this does not always have to be the best way, because in addition to costs, benefits can also be linked to the securing of materials in a depot, if certain economies of scale-and-scope can be achieved that cannot be achieved with a single reusable material. This also applies if materials must undergo processing to meet user demand again. Temporary storage is also necessary in such a case of upcycling.

In the chapter we assume a physical depot of materials, which is comparable to a wholesaler with a storage yard. However, this does not always have to be the case, because with a digital materials database linked to the blockchain registration, the building itself can also be seen as a depot, or urban mine.

10.2. INPUT

a. The materials resulting from the demolition process.
b. Depots to store the materials.
c. Discount rates for calculating the present value of materials over time.

10.3. PRODUCTS AND SERVICES

The central product in this chapter is not only the possibility to store materials in a way that retains their value, but also to be able to deliver them in such a way that they can be reused at the highest possible value. The storage of materials for a longer period is a loss of value of these materials because the materials cannot be used for productive functions in a building. We do not consider the speculative value of material stocks because of price changes.

The function of a stock is to fulfill various forms of questions from inexperienced users. To be able to combine these into new products, or to guarantee immediate delivery of a product, so that you do not have to wait for a building to produce new materials from a demolition process.

The extent to which demand and supply can be combined more quickly without losing time is therefore the central product in this chapter. Derived from this product is the reduction of the problem of damage, loss or waste associated with stocks of material, in accordance with the operational management of any planning company or wholesaler. The longer the time between a supply and demand match, the higher these costs will be, including loss through use, which can be visualized by the discount rate of loss of value of materials in depots.

10.4. Techniques, Templates and Tools

A materials depot has both a physical side, in accordance with the storage location at every wholesaler or distribution center, and a digital side in the form of a materials registration system. Such a system can be used for the administrative handling of inbound and outbound processes of the materials in a depot, as well as for an overview of the materials that are available for the sale of these materials. The materials registration system can be a specialization of the digital materials database or be linked to this database via an API.

10.5. Results

With a depot or stock, a condition is set up to bridge the supply and demand for reusable materials in a physical sense. The administrative and digital side of the depot enables us to organize the matching between supply and demand, and to provide an overview of all available materials, to prevent damage, loss, and waste. These results can be used in the next step of the sustainable deconstruction process, namely the trade of reusable materials based on their registered property rights.

10.6. Quality Factors

The quality factors that are important in the stocking and stock management of reusable materials are the same as those of the quality standards of wholesalers and/or distribution centers. Here too, for example, the application of a Lean philosophy can also be useful.

10.7. Process Activities

When securing the various materials in a depot, the following process activities are discussed:

a. The delivery of the materials in the depot (inbound)
b. The method of storage and stock management of the materials
c. The delivery of the materials from the depot based on order processing (outbound)
d. The digital administration of all inbound and outbound processes, partly based on the property rights of the materials from the digital materials database.
e. The continuous improvement of the various processes based on the quality standards and/or philosophy that stands for them.

10.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Each question has an answer:

Do you have a temporary depot to store materials for reuse? Or is such a depot set up at external parties, who, for example, also take care of the processing of the materials into reusable materials?
Respondent 1: Not yet. The fabricator supervises the processing of the materials, based on the requirements of the consultant.
Respondent 2: The materials to be sold or reused are stored on the site itself, in a part of the building that is preserved. This may be different for other projects. This storage problem will therefore be considered/answered in line with the project.
Respondent 3: Not yet for the building, but we have a depot for materials from infrastructure projects.
Respondent 4: Not us, but our goal is to create a depot to store material in every region of France. We are currently looking for internal sites.

Question: It is difficult and expensive to store used products and pass them on for reuse.
Answer: Work with material exchange platforms, such as Globechain and Collecteco. Also consider donating materials for social value creation.

10.9. COMMENTARY

There are no comments yet that can be linked to this chapter.

10.10. REFERENCES

References within projects

1. Storing materials at the French Railways – the Villeneuve St. George (VSG) project

Storage takes place for materials of which in-situ reuse has been confirmed or of which buyers have been identified for ex-situ reuse (according to the construction planning coordination Interreg/VSG). The construction company takes care of the storage (organization, fencing, security, cleaning, etc.).

a. Ex-situ storage of materials:

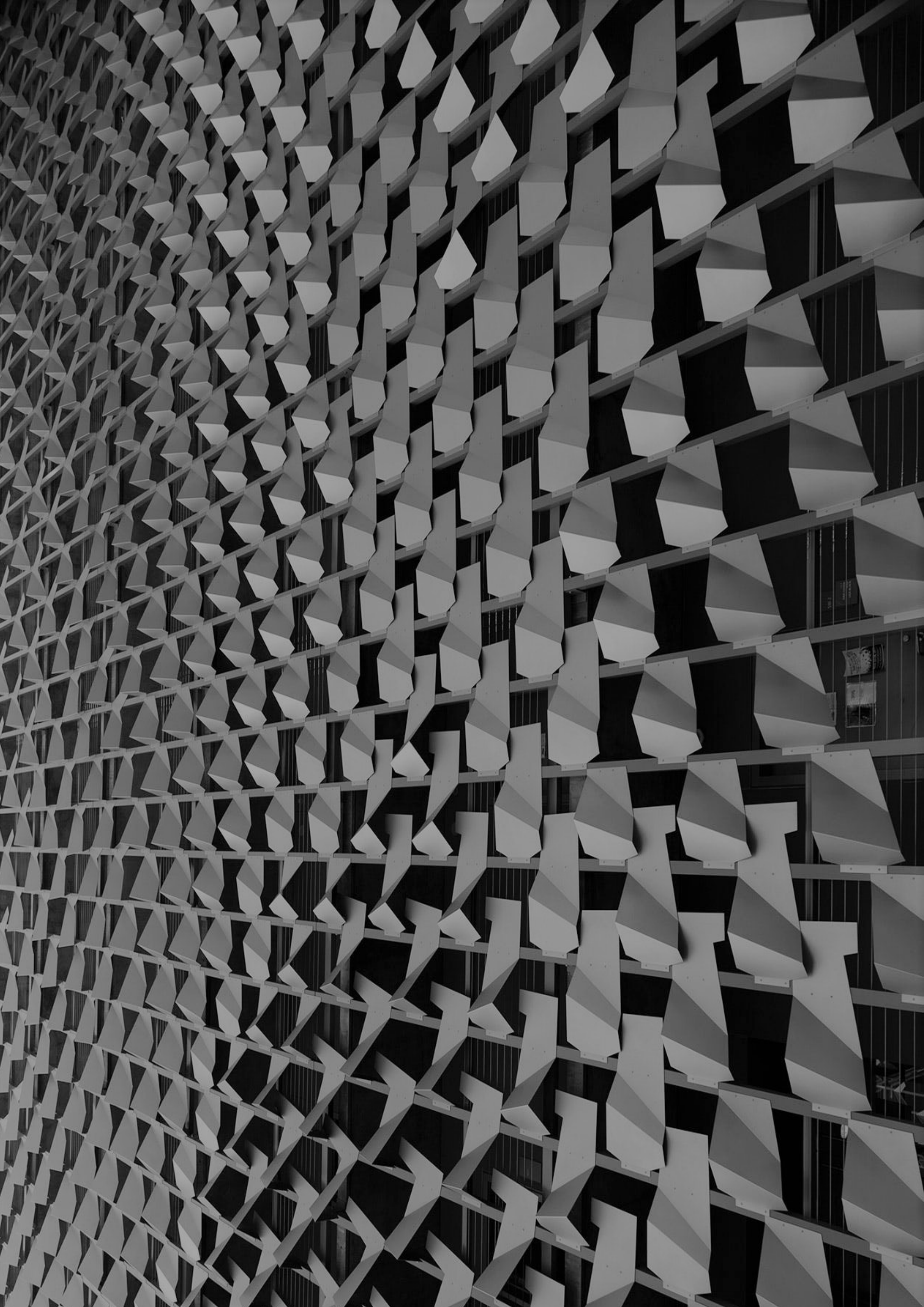
- If any potential ex-situ reuse material is sold, we charge between 200 and 250 m² of storage space.
- In the tender document, SNCF proposes two options for 9 months of 250m² storage for ex-situ reuse:
- A storage area designated by the SNCF around the construction site: a city car park rented by the city. Some limitations: The parking lot is in a flood zone and is accessed from a tunnel, avoiding for oversized materials (e.g., structural parts) to

move from the construction site to the parking lot. This requires more restrictive disassembly and new packaging considerations.

- A second zone to be identified by the construction company with an estimated cost of EUR 18,000. Several construction companies have estimated the costs for this zone at 10,000 to 100,000.

b. In-situ material storage:

- If potential in-situ is confirmed for the materials, we calculate approximately 90m² of storage space
- Glass: 16m² storage space
- Mineral/concrete cladding (roof): 27m² storage room
- Stone facade (canopy): 7m² storage space
- Ceiling: 15m² storage room
- Ceiling lamps LED 60x60: 2m² storage space
- Kitchen appliances: 20m² storage room
- Interior doors: 2m² storage space



11. PROCESSING

11.1 INTRODUCTION

The desired integral cycle of circular use of materials currently only exists for a few materials, such as metals. There is no cycle for the other materials, because after the materials have been used in a building, most of the materials after demolition (no disassembly) are landfilled, incinerated, or recycled in low quality. It is economically cheaper for these materials to buy new materials than to have existing materials undergo the operations of the cycle. However, for increased materials, this balance is beginning to shift, fueled by price increases for new materials, as well as pricing the social costs of destroying existing materials. This is done with instruments like liability and Co2 prices to produce alternative new materials (ETS rights).

Examples of waste processors of building materials show that waste is increasingly becoming a raw material, because after sorting and cleaning the materials, new raw materials are created that are competitive with primary raw materials. Same for products. Not because these secondary raw materials have really become cheaper, but because the costs of primary raw materials are rising explosively. This creates a business model for the cycle of secondary materials, in which inventories of the costs and benefits of actions in this cycle model are significant to give as many stakeholders as possible an integral insight into their own derived revenue model, which is often part of the entire cycle. This in comparison with a classic way of building and demolishing, in which the disappearance of materials is an issue.

A cycle that is not only based on the physical flows of the materials, but also has the underlying legal and market structures (market masters) to further organize long-term contracts with materials in the chain. Precisely because in the cycle several stakeholders are continuously connected with each other in an enforceable manner. In the classical way, this legal infrastructure is absent, which means that waste is the norm, because the cycle can never be closed due to the loose cohesion between stakeholders.

Many costs in a traditional way of demolition are caused by the transport costs to deposit the materials at a suitable waste location or at a location for low-grade processing of materials, as well as the processing of these materials. These costs must be mapped out for each project with low-grade material handling. It is expected that these costs will also rise, because increasingly higher demands are made on the processing of these materials. Even with low-grade reuse. However, these costs often have a local character. Because higher costs of "depositing" lower the relative costs of circular demolition, it is important that these costs, including the associated social costs, are tracked over time for strategic decision-making by each owner.

This also applies to the processing costs of high-quality material into new materials, or the direct reuse of material products. These costs, ranging from transport, cleaning, storage, and processing to new products, will also have to be made transparent, so that they can be included in strategic decision-making processes about the handling of materials from buildings. Local processing costs per material will primarily be the norm here but can be tracked on a central platform if various (pilot) partners also provide the data for this.

Through (hopefully) innovations, processing costs of low-quality and high-quality processing per material can be made increasingly clear. This requires investments in data collection and presentation, which can also be supplemented with examples that are used in other parts of the circular demolition process. Here we are still at the beginning of a process that needs to be further complemented within Digital Deconstruction and beyond.

11.2. Input

The following inputs are considered as input for the processing of materials

- Materials from the depots.

- Materials straight from a building.

- Material passports of the materials.

- The degree of "cleanliness" of the materials.

- The transport of the materials to the processor.

- Processing installations of materials as waste

- Tools for refurbishing, repairing, or restoring materials.

11.3 Products and Services

The central service in the processing of waste from building materials is the conversion of lower-quality materials to that quality of materials, so that these materials can be used directly again for a building, or are processed into semi-finished products, with which the industry can again produce new products for the construction industry. All this primarily without loss of material, leading to new values for building functions and minimizing the various environmental costs.

The services are provided in processing plants, where massive quantities of construction waste are sorted based on various aspects, such as size, type, beauty, etc., and ultimately processed into clean granulate of this material. Whether it concerns "refurbishment hubs" where products for the construction industry are repaired or, for example, made to measure. This can also involve a range of products and materials, but it is paramount that no physical piece of material is lost.

11.4. Methods, Techniques, Templates and Tools

The methods, techniques and instruments used in processing plants belong specifically to this company. For the time being, it goes too far in this Handbook to go into detail about this.

11.5. RESULTS

The results of the treatment process are the availability of secondary materials for the construction, renovation, and maintenance of buildings. And at a social value that is comparable to the price or value of primary materials. The quality of the secondary materials is known, the alignment with the demand of new users, as well as the availability of these materials is organized.

11.6. QUALITY FACTORS

Quality plays a leading role in the reuse of materials in buildings. The processing or recovery process of materials therefore aims to restore the functional and relational quality of the materials, in such a way that they meet the needs of the new owner of the materials and do not impair the safety and functionality of the materials.

11.7. PROCESS ACTIVITIES

The process activities that are used at processing plants belong specifically to these companies. For the time being, it goes too far in this Handbook to go into detail about this.

11.8. QUESTIONS AND ANSWERS

Question: Costs associated with reprocessing or cleaning materials (e.g., recycled bricks) and uncertainty that materials will meet warranties and performance specifications.
Answer: When specifying recycled materials, only purchase recycled items that have a warranty. These costs and risks are expected to decrease as the industry becomes better equipped to support a circular construction sector (e.g., circular infrastructure development, increasing awareness of recovery processes, etc.).

11.9. COMMENTS

1. Interview with Renewi, waste processor of building materials in the Netherlands

In Belgium, a new law has come into effect. This will apply from January 2023. According to this law, recyclable waste may no longer be incinerated, but only processed. The aim is to process materials cleanly because pollution can arise during the processing of concrete, for example, or from contamination in the concrete itself. Biobased fibers and synthetic fibers may be contained in concrete. Steel fibers are not, because they will erode. This can cause chemical contamination or weaken the structure.

In general, it can be said that little research has been done into the reuse of materials by waste processors or other parties in the chain. An example is concrete. It is well known that there are chemical residues in concrete, which can lead to safety risks because of pollution and construction weakening can also occur. In fact, there is yet no legislation for the reuse of concrete. Only NEN 2767 comes a bit close.

Renewi indicates that a major transition is taking place in container processing. For example, materials are becoming increasingly valuable and the demand for reuse is growing. Material passports can be particularly useful for waste disposal. Usually little or nothing is known about waste that comes in now.

Waste processing is becoming more sophisticated. Large installations are required to process mixed flows. A new processing installation is being built in Heerlen (The Netherlands). The design of new installations saves a lot of materials and therefore also CO_2. Renewi indicates that this is approximately 23,000 tons of Co2 per year. This has a value of € 1,472,000. - according to the current prices of Co2 rights.
Renewi indicates that waste processing is becoming increasingly large-scale, partly because proper processing of waste yields new materials with a high added value. Given the rising prices of primary and therefore also secondary materials, nowadays the delivery of materials to the processing installations is also paid for.

2. Further analysis when processing materials – guidelines for the Handbook

1. The clean delivery of materials to a processor increases the costs of the demolition company or the dismantling company, but results in higher quality materials when processed. And thus, more revenue for the processor, or lower costs for dumping or incineration. The processor will share this higher gross margin with the wrecker for his or her preliminary work.
2. Making a 3d scan during the inventory process reduces the costs of the removability analysis for a building, because 3d data can be read directly into a BIM model for this analysis. This subsequently lowers the integral costs of the inventory, so that the overall business case for the cycle is more accurate.
3. Inventory of materials improves the transparency of the materials, especially about quantity (removability) and quality. Transparent quality increases the value of these materials ("the Lemon problem"), after which the costs of inventory could be paid from the sale of the materials.

The cycle of materials can be improved repeatedly with comparable examples. The aim of the Handbook is to share and safeguard these examples, so that the different stakeholders know from each other why the action of one can also be beneficial for them. So, if I make a 3D scan at the front of the cycle, how does that lead to a cost saving for the purchaser from the processor, who in turn makes new raw materials or products with the right quality.

Or vice versa, if the processor is going to pay for the purchase of waste, this means a direct incentive for the storage of materials, as well as the demolition or dismantling company, to work very efficiently and effectively, because landfill and incineration costs are avoided, and they will be paid more for the supply of "raw secondary raw materials." In this way, the Handbook responds to the prevention of "system failure," i.e., insufficient coordination of value-added actions by successive chain partners, because of which the business model in the next chain in the chain is negatively influenced or even destroyed. The Handbook makes these costs, benefits, and associated actions transparent, so that parties in the cycle can make better agreements about quality, as well as the compensation for their extra part in the chain.

The demolition company or the dismantling company then has an incentive to know exactly where valuable materials are present in a building, whether they can be removed efficiently and without or little loss of value, etc. There will also be an incentive for the "warehouse master" of the cycle to drastically reduce the costs of stocks and storage with rapid delivery to the processor, who makes granulate from it, for example, instead of weighing storage costs against the costs of landfill or incineration. The latter costs of waste, including their social costs, will then disappear, or at least be drastically reduced.

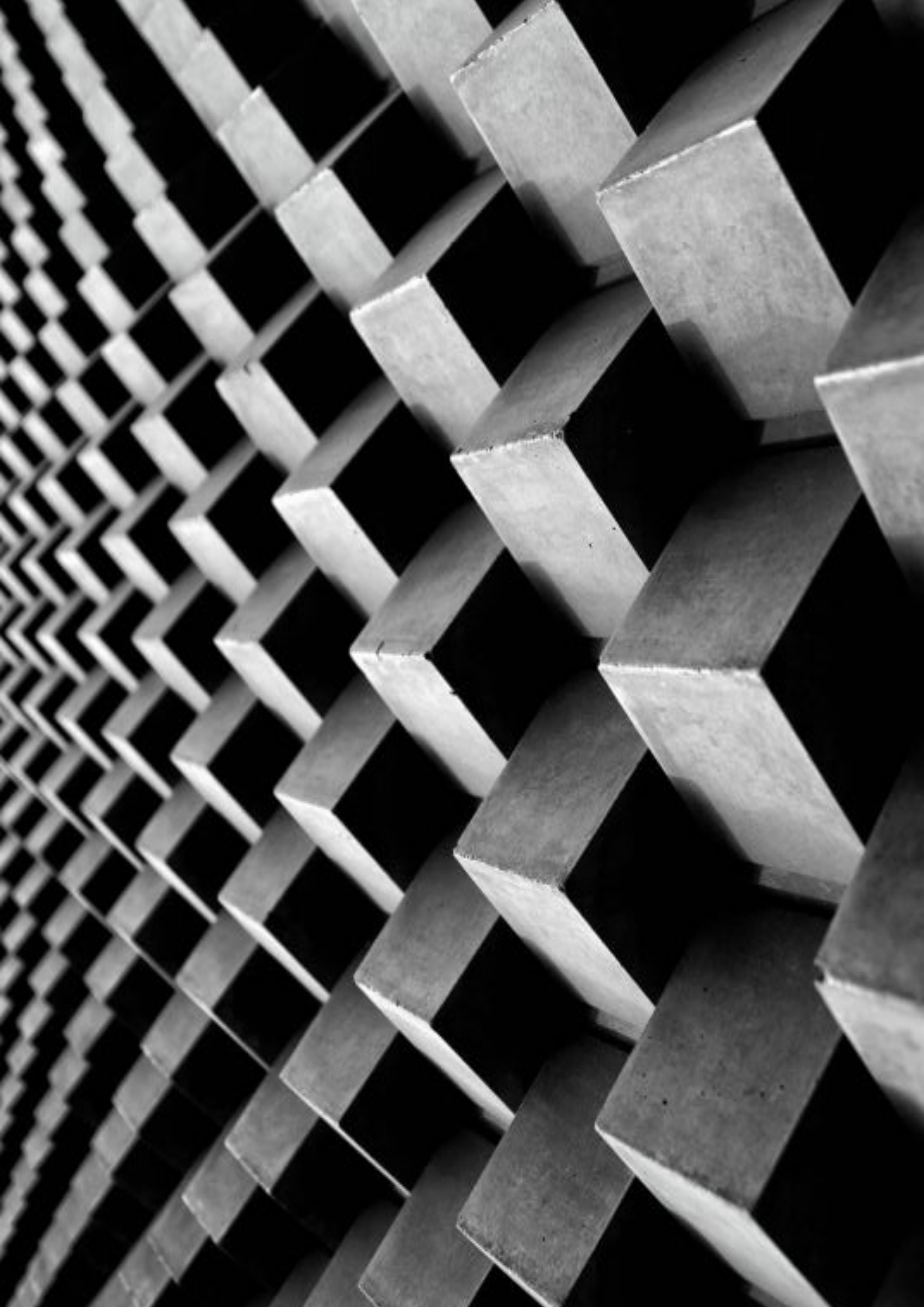
In this cycle approach, we can then not only determine the additional costs and additional benefits for each link of an extra step for the next link on the way to a closed cycle, but also gain insight into the nature of a disruption. As the case of the processor shows, improvements in some links require investments. And some investments cannot always be paid for directly from a company's liquidity. Or where there is a temporary unprofitable top, as is the case with the marketplace for trading the “titles/tokens” for materials

These obstacles can arise in the cases and must be mapped out with the descriptions in the handbook. They will then be placed on the “fund list,” to which government funds or investor funds can be linked

Three lines/scenarios are provided for searching for information and sources of the manual:
1. Mapping out the direct visible costs of all operations in the cycle (classical or circular), expressed in euros per 1,000 kilos of glass, polymers, and concrete. Each cost description is given a paragraph in the manual for the appropriate part.
2. Mapping the efficiency successes of investments and innovation in one part of the cycle on the other parts of the cycle on the way from classical to circular (interventions). For example, from inventory on demolition/dismantling, or from processing to the purchase of raw materials. Each time expressed in euros per 1000 kilos of glass, polymers, and concrete. Each intervention is described in the relevant section in the handbook. A list will be made of types of interventions throughout the cycle, ordered by link-on-link effect.
3. Mapping the effects of “tipping points”. That is, of events that lead to the closing of the cycle instead of disrupting the cycle. For example: earning money from the delivery of waste, instead of paying for it. Or setting up a marketplace for the trading of rights to materials. Tipping points result in major behavioral changes for all stakeholders and subsequently cause major disruptions in the development of a market. Each “tipping point” belongs to a particular link in the cycle, which is described in the manual.

11.10 REFERENCES

There are no references to this chapter yet, other than those listed in the comments section.



12. Marketplaces

12.1. Introduction

Available materials can find a new owner by making these materials part of a transaction between a buyer and a seller of these materials. Buyers and sellers can efficiently transact these transactions on a marketplace. This can be a digital or physical marketplace. To function as a marketplace for reusable materials in an efficient and effective manner, the marketplace must meet several requirements. These requirements can also ensure that the operation of this marketplace is so effective and efficient that the value of the various materials also increases as a result. An effect that can have its effect throughout the entire chain, as described in this Handbook.

In the process prior to the sale of materials from a building, these materials are processed, the origin and quality of the materials are registered and verified, so that problems arising from asymmetric information (the "lemon" issue) do not arise. This means that in terms of costs only those costs are incurred that are related to the process of sale or alternative internal use of the materials, as well as the possibility to convert the saved CO2 emissions into tradable emission rights and the sale of these rights.

Because the social return of saved Co2 cannot yet be converted into money, the financial return will be equal to the value of the materials on a (digital) marketplace, which is comparable to primary materials with equal quality, minus the sales commissions of the digital marketplace. In other words:

$Mc = Mb+Mm-P$

Whereby:
Mc = the proceeds from the sale of materials
Mb = the financial income from the sale of materials
Mm = the social revenue from the sale of materials
P = the commission on sales related to the marketplace used for the sale.

To follow Mb, prices will have to be determined for all materials. If these materials are not traded directly, the shadow price of the primary materials can also be used. Given the price formation in local markets, a cost-benefit analysis will require averages for multiple markets to provide the correct data.

To track Mm in money, the amount of Co2 saved from a material must be known. This saving, as well as the size of the materials, can then be multiplied by the CO2/ton price of emission rights, which is traded on the EEX. This emission price is currently around 65 euros per Co2/ton (1 October 2022).
The commission on the sale of materials assumes that there is a market for reusable materials. However, these are currently very local or non-existent. Normally, a commission on a transaction varies between 0.5% and 5% of the value of the material.

For a strategic analysis of the costs and benefits of circular demolition vs. classic demolition, the different selling prices of the most common materials in each environment must be continuously monitored to correctly implement this strategy. This also applies to the shadow prices for saved CO2, which can only actually be included in the cost-benefit analysis if the rights to the saved CO2 are also tradable. Now they can be called only in technical and quantitative terms.

12.2. INPUT

1. Available materials, including the ownership rights to these materials, as recorded in the blockchain registry linked to the digital materials database.
2. Buyers.
3. Sellers.
4. Information about the materials in terms of quantity, quality, and availability.
5. Prices of the varied materials.
6. Market accessibility in terms of market entry and exit conditions.

12.3. PRODUCTS AND SERVICES

The central product in this chapter is a (digital) marketplace for reusable products. The marketplace has suppliers of materials who can offer their materials for sale, demanders/buyers of reusable materials, and a market master who can connect supply and demand. In fact, the market master is the party that sets and creates conditions behind the (digital) marketplace. The costs generated by this process, as well as the value created by the connection between supply and demand, are the basis for the remuneration of the market master's services. A fee from which the market master must be able to pay the costs for the digital marketplace.

Supply and demand are digitally matched and implemented through the exchange of ownership rights in the materials, not necessarily by changing the physical presence of the materials as well. This can remain in the depot, or even remain inside a building, if the materials have not yet been detached from the building itself.

12.4. TECHNIQUES, TEMPLATES AND TOOLS

The product of the marketplace is made accessible using an IT application, which allows buyers and sellers to contact each other. A digital marketplace, connected to the digital materials database and property rights module via blockchain technology. The Blockchain registration gives the ability to track and trace products through the way the blockchain is organized i.e., each new owner in a chain of activities or ownership means an additional block or ledger is added. In this way, the follow-up of sold products can be monitored.

Other tools are:
- Various follow-up templates and standardized follow-up documents related to transactions with materials.
- Templates related to the traceability and traceability of materials.

12.5. RESULTS

The result of a marketplace is the successful transaction, expressed both in terms of transaction volumes and the total value of transactions.

12.6. QUALITY FACTORS

To function properly as a market, a market must meet the following requirements:

a. The quality of the materials to be traded must be transparent.
b. The ownership of the materials must be transparent and legally secured.
c. Access to the market and the conditions for selling and buying materials should be made transparent.
d. The prices of the materials must be able to be continuously maintained.
e. The settlement of purchase agreements must be able to be settled automatically.
f. When settling a purchase agreement, the buyer must be able to indicate whether and, if so, to which physical location the materials must be delivered.
g. The financial settlement of a transaction on the digital market and the compensation for these transactions for the market master should be able to be settled automatically.

12.7. PROCESS ACTIVITIES

When trading the reusable materials on a (digital) marketplace, the following process activities are discussed:

a. Physically setting up the marketplace in the form of a digital application.
b. The legal organization of the marketplace so that buyers and sellers can enter the digital marketplace.
c. Publish information on marketplaces. To date, there are several well-known existing e-marketplaces. They are different for each country and between regions. Some e-marketplaces are "national", but 90% of the published elements are in a specific area. Try to find an e-marketplace that has launched in your area. Let information about the destination of the product (to be stored, immediately implemented, sold...) be indicated by the intended stakeholder. Additional aspects are discussed and checked.
d. Send information by e-mail to your network (all actors identified earlier), publish an information on your own website.
e. The legal shaping of transactions in the market in the form of auto-settled agreements, both in terms of transfer of money, in terms of physical delivery, and in terms of remuneration for the market master.
f. Organizing management and supervision of the market and the various transactions.
g. Applying a process of continuous improvement.

12.8. QUESTIONS AND ANSWERS

The following questions have been raised in projects on this subject. Every question has an answer.

Do you or your customers use an internal marketplace for materials?
Respondent 1: Not yet. We are developing, in collaboration with other companies, a physical platform to store the deconstruction materials and elements. It should be launched in 2022.
Respondent 2: Yes, we have an internal marketplace.

How do you or your clients calculate the value of recycled materials? From an internal (market) place or with the help of an external marketplace?
Respondent 1: The company makes an estimated valuation responsible for the assessment of the project (consultant), based on their contacts. The demolition company calculates the demolition costs about the treatment required by the consultant.
Respondent 2: Not yet done. The first approximation should be ¼ to a third of the price for new material.
Respondent 3: We have no experience with this yet. The consultant is currently investigating which method can be used for this.
Respondent 4: The responsible company (advisor) makes an approximate estimate. The deconstructor values the demolition costs about the treatment the consultant needs
Respondent 5: The value of a reused material is compared with a new material that would have been purchased. This value is not linked to the marketplace.

Do you or your client also sell materials from a building to third parties? Or does that only work for your demolition company?
Respondent 1: Depends on the contract.
Respondent 2: Only for the demolition company. Sale of the materials through the owner (CFL). Test at the pilot site Ettelbrück
Respondent 3: Not relevant to date. In the upcoming construction works there will also be sold to third parties
Respondent 4: Depends on the contract.
Respondent 5: Yes, we can sell materials to third parties.

12.9. COMMENTARY

The following comments can be made about this chapter.
• Management of the dismantled products via the dismantling company.
• Control of the dismantling works and the storage via the architectural or engineering offices.
• Use accurate and serious traceability methods, documents, and tools. Applicability must be clear in all tenders.
• If you have a physical repository, add a digital method/tool to track transactions. Also define delivery, entry, security, and exit rules.
• Push to use/sell the products quickly. The longer the time between a supply and demand match, the higher these costs will be, including loss through use, which can be visualized by the discount rate of loss of value of materials in depots.

• Define the transport method and packaging in advance for the transport (do not wait until the last day). Ask construction companies or specific suppliers how new products are packaged, search the internet and reuse reports/manuals.

12.10. REFERENCES

References within projects:

1. Destinations of materials in the project in Lomme (Vilogia: France):
- Concrete from the site can potentially be recycled into concrete aggregate or road aggregate.
- Ceramic elements can be used in road construction.
- The gypsum waste from construction sites can be converted back into gypsum powder and re-introduced into the production process of new drywall, companies have already been identified by Neo-Eco (construction supervisor)
- The floor covering can be recycled into energy or landfilled. The aim is to make as much use as possible of energy recovery.
- Polystyrene and fiberglass from deconstruction are currently not recyclable (nor reusable) as they are considered contaminated. They will be put in a landfill.
- In general, if reuse is not possible, the deconstruction metals go back to the metallurgical industry to be melted down and create new products.
- During the demolition of the site, metal elements such as sink taps, boilers and pipes were cleaned during the deaeration phase in the houses. The presence of lead paint will affect the possibility of reuse.
- Re-use of joinery is possible but is done on a case-by-case basis, depending on the presence of asbestos in the joints, their general condition, or the demand for their dimensions.
- As for the wood, it is usually a class B wood, lightly treated. It is thus possible either to reuse it directly, or to use it for material recovery in the manufacture of wood panels, or to use it for energy recovery by incineration.

2. Uses of materials in the project in Villeneuve St. George (AREP, France):
AREP's reuse expert is responsible for publishing materials online on Cycle Up Platform, contacting potential buyers and organizing an appointment between the buyer and the construction company. The Cycle Up platform verifies the publication and sends the invoices to the buyers and the order to AREP. The money is recovered to the SNCF, but Cycle Up takes a 10% commission on the sale (previously 5% but it has changed).

2. Destinations of materials in the project in Croix Luzet (Lyon, France):
• Association with marketplaces and local players (made in the past, Cycleup, etc.). In this way all buyers were found before the demolition of the building took place.
• Several and dispersed marketplaces: platforms should at least have sufficient stocks to create, for example by pooling with the tertiary sector.”

CONCEPTS AND GLOSSARY

Construction waste: the total of product loss due to breakage during transport, product loss due to damage/breakage on the construction site, sawing waste on the construction site and additional ordered material (3.42) (for smooth processing)

Construction product: product (3.60) that is supplied to the construction site and after processing is part of an element (3.21)

Circular construction: development, use and reuse (3.29) of buildings, areas, and infrastructure, without unnecessarily depleting natural resources, polluting the living environment, and damaging ecosystems by using as many renewable raw materials as possible (3.31). Circular construction is building in a way that is economically, socially, culturally, and ecologically responsible, in the Netherlands and beyond, now and in the future.

Circular economy: economic system in which the use and value of raw material flows is optimized, without hindering the functioning of the biosphere and the integrity of society [SOURCE: Platform CB'23 Lexicon circular construction]. In a circular economy, the aim is to protect biological and technical material stocks, avoid environmental impact and preserve existing value.

Element: (abstract) part of a (construction) work (3.11) that is distinguished solely based on a required function [SOURCE: Circular Building Framework version 1.0] Examples of elements are room separation, supporting structure, lighting, heating, and security.

Environmental performance of buildings MPG: summary of the environmental costs (3.49) per gross floor area [SOURCE: Platform CB'23 Lexicon circular construction]

High-quality reuse: process to convert secondary raw materials (from reuse or recycling) into new materials, components, or products of better* quality, functionality and/or higher value.

Life cycle: successive and coherent stages of a product (3.60) or service system in its current function and location: design, raw material extraction, production, distribution, use and end-of-life treatment (3.22) [SOURCE: Platform CB'23 Lexicon circular construction]

Life cycle assessment (LCA): Method for determining and evaluating the input (3.33) and output flows (3.57), and potential environmental impact (3.47) of a product system (3.62) during its life cycle (3.36) [SOURCE: Platform CB' 23 Lexicon circular construction]

Low-grade reuse: the process of converting secondary materials (3.70) parts or products (3.60) from reuse (3.29) or recycling (3.63) into new materials (3.42), parts or products with lower quality, reduced functionality, or lower value than their original application 269 [SOURCE: Platform CB'23 Lexicon circular construction. Pollution and mixing can result in low-value instead of high-value reuse.

Material: processed raw material (3.27) used for the manufacture of construction products (3.10) [SOURCE: Platform CB'23 Lexicon circular construction]

Material balance: Counting components belonging to a system or process under study. A material balance is the result of a 'material flow analysis'.

Material flow analysis MFA: analytical method to analyze material flows within a well-defined system

Materials passport: digital documentation of an object or sub-object (3.15) in the B&U or civil engineering sector stating what an object or sub-object consists of - both qualitatively and quantitatively - how it is constructed and where it is located [SOURCE: Platform CB '23 Lexicon circular construction.

National Environmental Database (NMD): database with product cards (3.61) and associated environmental profiles (3.53), which is used to determine the environmental performance (3.51) of construction works (3.11) [SOURCE: Determination method environmental performance of construction works]

Non-renewable raw material: raw material (3.28) of abiotic or biotic origin that is not grown on a human time scale (3.46), naturally replenished, or naturally cleaned and/or does not come from a production unit that is managed sustainably (3.17) [SOURCE: Platform CB'23 Lexicon circular construction]

Physically scarce material: material (3.42) that is limited in natural resources, i.e., is scarce based on available resources of raw materials and the risk of their depletion.

Primary material: (building) material (3.42) produced from primary raw materials (3.59) [SOURCE: Platform CB'23 Lexicon circular construction]

Primary raw material: raw material (3.28) that is produced by the earth and that is used by people for the production of materials (3.42) and products (3.60) [SOURCE: Platform CB'23 Lexicon circular construction] Product that is used by the supplier in the marketed and what is purchased by the customer for use during the life cycle of a structure (3.11) A product can be a physical product (for example 1 m2 of frame), but also an activity (for example 1 km of rail transport). [SOURCE: Determination method for environmental performance of buildings]

Raw material: basic material that is used in a process to make goods, energy, construction products (3.10) or semi-finished products [SOURCE: Platform CB'23 Lexicon circular construction]

Recycling: the recovery of materials (3.42) and raw materials (3.28) from discarded products (3.60), and their reuse to produce construction products (3.10) [SOURCE: Platform CB'23 Lexicon circular construction]. Recycling is one of the R principles.

Removability: Degree to which a composite construction product (3.10) or element (3.22) can be disassembled non-destructively [SOURCE: Platform CB'23 Lexicon circular construction] Detachable construction products or elements can preferably be disassembled as simply as possible. As a synonym for 'detachable', 'dismountable' is sometimes used.

Renewable material: material (3.42) produced from a renewable raw material (3.31) [SOURCE: Platform CB'23 Lexicon circular construction]

Renewable resource: resource (3.28) from a resource that is cultivated, or naturally replenished or cleaned on a human time scale (3.46) [SOURCE: Platform CB'23 Lexicon Circular Construction] A renewable resource can be depleted yet persist indefinitely with good stewardship. Examples include trees in forests, grasses in grassland, fertile soil. A renewable raw material can be of both abiotic and biotic origin.

Repair: longer use of construction products (3.10) or construction works (3.11) through preventive or corrective maintenance (3.56) during the use phase [SOURCE: Platform CB'23 Lexicon circular construction]

Residual value: market value of products (3.60) and raw materials (3.28) at the end of their useful life or technical life (3.77) [SOURCE: Platform CB'23 Lexicon circular construction] Repair is one of the R principles.

Reuse: reuse constructions, construction products (3.10) or building or civil engineering work parts/elements (3.21) in the same function, whether after processing [SOURCE: Platform CB'23 Lexicon circular construction] Reuse is one of the R- principles. Examples of reuse are the reuse of an insulating material as an insulating material, a door as a door and a roof as a roof.

R-principles circular strategies (3.14) that all start with an R in English [SOURCE: Platform CB'23 Lexicon circular construction] In different R-lists there are 7 to 10 R-principles. Examples of R principles are recycling, reuse, and maintenance. R principles are widely used to think about and improve circularity. The R principles include reuse, repair, and recycling, for example. The main distinction between the R principles and the core measurement method is that the core measurement method measures circular impact. The R principles can only be used to see whether a circular strategy has been applied. The basic principle of the core measurement method is that it can measure the impact of any circular strategy, including that of the R principles. Often the R principles are presented in a ladder. The suggestion is that a strategy higher up the ladder contributes more to circularity. However, the circular impact differs per application. The core measurement method can make those differences visible, the R principles cannot.

Recycling: recovering materials and raw materials from discarded products and reusing them to make products.

Secondary material: material (3.42) that replaces primary materials (3.39) or other secondary materials and that originates from previous use or from residual flows from another product system [SOURCE: Platform CB'23 Lexicon circular construction]

Secondary material from reuse: material (3.20) that is part of a composite (sub) object (3.15) that is reused for the same function after a previous application (whether after processing)

Secondary material from recycled material (3.42) that has undergone a recycling process (3.63) and is reused in an object or sub-object (3.15)

Socio-economically scarce raw material: raw material (3.28) that is scarce in terms of supply and economic importance

Socio-economically non-scarce resource: resource (3.28) that is not a socio-economically scarce resource (3.73). Materials that are not on the list of critical materials [11] also fall under socio-economically non-scarce.

Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs [SOURCE: Platform CB'23 Lexicon circular construction]

Technical cycle: cycle in which products (3.60), parts and materials (3.42) are repaired (by human action) so that they can be used again in the economy as new products, parts, and materials [SOURCE: Platform CB'23 Lexicon circular construction]

Value retention: high-quality reuse (3.29) of objects or sub-objects (3.15) and/or their raw materials (3.28) Value retention is maximized by striving for comparable or higher-quality functionality when reused.