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White paper

Social Cost-Benefit Analyses Reuse of Materials in Buildings

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1. Introduction

In his 1937 article "The Theory of the Firm", Ronald Coase called on everyone to take a closer look at the transaction costs of a firm in its relationships with customers, suppliers, personnel, and organization compared to the costs of individual contracts that everyone can arrange with each other for every transaction one makes. For example, for each hour of work rather than a longer-term employment contract, etc. And to address this on a case-by-case basis.

The comparison between a classical way of demolition and circular demolition raises 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 what investments, forms of regulation, the different costs and benefits can be represented in such a way that circular building and demolition has a clear added value.

The reuse of materials in buildings is a topic of research that is gaining considerable importance. This involves goals that involve a combination of savings on raw materials, the prevention of Co2 emissions in the production of these materials, energy savings and self-sufficiency in materials in Europe. Reuse of materials benefits from a large number of investments related to production, assembly, use, disassembly, processing, and reuse. And with all these steps, the question is whether the chain of activities adds value, so that each actor in the chain can also cover his or her costs. A tool that can help here is a social cost-benefit analysis.

A social cost-benefit analysis can be described as an analysis of the social costs and social benefits of a project or measure. The balance of the costs and benefits indicates how interesting it is to invest in a project. Even if these costs and benefits are not easily measurable, as in the social domain.

In essence, a social cost-benefit analysis for the purpose of project assessment, for example the choice between classic and circular demolition of a building, always looks the same in terms of structure, regardless of when it is carried out. The purpose of drawing up a social cost-benefit analysis does, however, depend on the time of the project appraisal. Ex-ante, the cost-benefit analysis serves as a tool to assess the added value and scope of a project. During the project, a social cost-benefit analysis can provide insight into the effects of the project during implementation. After completion, a social cost-benefit analysis shows whether the expected results have been achieved. Depending on the moment in the process, a social cost-benefit analysis therefore serves a different purpose.

In summary, a social cost-benefit analysis provides building blocks for decision-making regarding demolition or dismantling (classic vs circular demolition) the following questions:

- What are the likely impacts of the project?

- Does the project thereby contribute to social welfare?

- Which interpretation of the project (alternatives) is preferable?

- Are there possibilities to optimize the project?

- Who will benefit from the advantages and disadvantages of the project?

- To what extent is a financial contribution (or subsidy) from the (national) government to the project reasonable?

2. Definitions and methodology

An economic project assessment of investments related to circular construction and demolition involves the systematic, rational substantiation of the social choice between relevant alternatives. In this case, these are a traditional method of demolition versus a circular method. All social aspects must be considered, including non-financial aspects such as safety, environmental or social effects. Because an economic project assessment looks at all social aspects, including saved CO_2 emissions, waste of scarce raw materials and energy use, it is better to speak of a social cost-benefit analysis rather than a cost-benefit analysis.

A social cost-benefit analysis not only looks at the effects of the selected measure. It also looks at possible alternative measures. In any case, at least two alternatives are always compared. In the terminology of the cost-benefit analysis, we speak of a project alternative (implementing the measure) and a zero alternative (best alternative without the measure). If there are several realistic alternatives, several project alternatives can be formulated.

A social cost-benefit analysis first looks at the so-called physical effects or quantity effects of a measure. The extent to which these effects can lead to welfare effects is then examined. These are therefore effects that can lead to increased prosperity. The concept of prosperity is broadly defined in a social cost-benefit analysis. In a cost-benefit analysis, there is in fact no difference between the terms welfare and well-being. To gain insight into the welfare effects, insight into changes in behavior is needed in all cases.

An important part of a social cost-benefit analysis is the term economic project assessment. Economic in this sense has a different meaning than 'financial'. Economic here refers more to the way in which the matter is viewed and less to the financial background of a measure.

A further characteristic of a social cost-benefit analysis is that all effects are included, i.e. not only the effects on the project initiator or the specific target group, but all those who are affected by the benefits and disbenefits. It is explicitly about the costs and benefits for all individuals and groups in society. In our case, therefore, in particular to the value of saved Co_2 emissions by reusing materials, because by reusing new production and the associated Co_2 emissions are avoided.

A cost-benefit analysis thus takes two steps beyond what is often usual in decisions about measures:

1. Multiple project alternatives are explicitly compared. It does not just consider whether one particular measure is possible and effective.

2. The costs and benefits of the project for all relevant parties are considered.

The fact that the effects of a measure are broader than initially intended does not have to be a limitation for conducting a cost-benefit analysis. On the contrary, a cost-benefit analysis necessitates the identification of the broad spectrum of effects, which makes it possible to highlight the interrelationships between the various fields of activity. In a cost-benefit analysis, it is important to visualize the effects on society and not to stop at the boundaries of the field of activity. Section 6 of this white paper pays particular attention to this issue.

2.1. What do the results of a cost-benefit analysis say?

As mentioned earlier, a cost-benefit analysis helps in good decision making. It provides insight into the expected effects and the relationship between social costs and benefits. In cost-benefit analysis terminology, a social cost-benefit analysis provides a picture for/of:

- the relationship between measures and effects;

- an integral consideration of various effects;

- the distribution of costs and benefits;

- project alternatives;

- risks and uncertainties surrounding the project.

To avoid false expectations, it is important to discuss two important features of social cost-benefit analyses here. Firstly, the strength of a social cost-benefit analysis is that all effects are presented under the same heading. For the integral assessment of various effects, everything is brought under one denominator (namely: euros).

In practice, expressing (monetizing) all effects in euros is hardly possible, if at all. Therefore, one should not be blinded by the balance of costs and benefits. The effects which cannot be quantified and the effects which can be monetized must also be included in the consideration of whether to invest in the project.

Second, for a good cost-benefit analysis, the effects must be determined. An ex-ante cost-benefit analysis is in fact about making a prediction of the future. Predictions are, of course, surrounded by uncertainties. These must always be considered when interpreting the results of a social cost-benefit analysis. The balance of costs and benefits therefore emphatically does not tell the whole story. It is important to have insight into the steps taken and how the effects and benefits were determined. In addition, information on effects that cannot be quantified is essential for careful decision-making. In whatever phase of the project. A cost-benefit analysis is one of the possible approaches for looking at a project. Even if a negative balance of costs and benefits results, there may still be good and weighty arguments for investing in the project.

An important point to consider when determining the costs and especially the effects of the investments and the resulting benefits is that this places very high demands on the available information, such as the quantity and type of materials in a building, the removability of these materials and the physical quality. When certain information is not available, it must therefore be managed pragmatically. It is important that it is clearly stated how the effects and benefits have been achieved. This allows the results of the social cost-benefit analysis to be placed in the right perspective. These are recommendations that are important to follow in a social cost-benefit analysis.

2.2. What steps does a social cost-benefit analysis consist of?

For the preparation of a social cost-benefit analysis, a general framework of the steps to be taken can be presented.

These steps are:

1. Problem analysis

2. Definition of project alternative

3. Definition of zero alternative

4. Determine costs

5. Determine effects

6. Determine benefits

7. Draw up an overview of costs and benefits

8. Variants and risks analysis

3. From Problem Analysis to Zero alternative

3.1. The Problem Analysis.

A good description of the problem analysis provides a good introduction to the reasons and objectives of the project. In addition, the problem analysis is important for determining various project alternatives (Step 2).

This white paper focuses on the problem of alternative use of materials in a building, as well as avoiding waste of materials and resources, Co2 emissions and saving energy. We are therefore looking within Circular Construction and Demolition in broad terms:

a. An overview of the available materials in a building

b. An overview of the alternative uses of these materials

c. An overview of the economic value of materials that can be reused

d. An overview of the societal benefits of reusing materials

3.2. Definition of project alternative

The project description (step 1) shows the elements that form a functional part of the project. For the project alternative, one can additionally look at different variants of the project and the phasing of the project, such as:

- What people and resources will be used for this project?

- What activities will be conducted with it?

- Which people will be reached by the measure?

- How many people are reached by the measure?

An important point to consider when describing the project is the demarcation of the project (what still belongs to the project and what no longer belongs to it?). It is preferable to include those elements in the project that are inextricably linked to achieve a solution to the problem. In the case of the reuse of materials, the project involves the total of the process steps of inventorying, disassembling, storing, processing, and reusing materials in a building. Or in classic demolition: the demolition, removal, and disposal of materials as quickly as possible, according to the adage make, use, throw away. The latter is the null alternative (see also step 3)

3.3: The zero alternative

The description of the null alternative is like the description of the project alternative and, in any case, addresses the alternative solution. In our case this concerns a classical way of demolishing a building.

3.4. Summary of steps 1 to 3

Within the methodology of Circular Demolition, two equations are therefore central, distinguishing between classical demolition and circular demolition or dismantling. The first is the null alternative and the second project alternative. The equations are written down in terms of costs and benefits:

1. $K = O + Sk + Dk - Mk$

2. $C = O + I + Sc + Dc + R - Mc$

Where the letters stand for the following aspects of the demolition and/or dismantling process:

K = The costs and benefits of the classical method of demolition

C = the costs and benefits of the circular method of dismantling

O = the organizational costs of the demolition and/or dismantling process

Sk = the costs of the classical services of a demolition company

Dk = the cost of removing and disposing of the materials after demolition

Mk = the proceeds of materials from a classical demolition process

I = the cost of inventorying and recording the materials in a building with a materials passport

Sc = the cost of the circular services of a demolition company

Dc = the cost of disposing of, 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 use materials

Mc = the return of materials from a circular demolition process.

The purpose of the social cost-benefit analysis is first to determine what exactly the above variables embrace in a specific situation. And which aspects can ensure that the additional efforts in a circular process also result in additional benefits, so that the $K > C$, or in other words to the situation where the costs of the classic demolition process are higher than those of the circular demolition/dismantling process.

Or described the other way around, when a circular demolition process adds value, on which an organization can determine its strategy as an organization and in terms of building, land, and materials. If the strategy is clear then it is also easier to initiate the long term investments in circular demolition and to use the tools that go with it.

The methodological explanation is therefore a basic framework, within which the use of tools relating to Circular Demolition can be placed, because without a clear purpose the added value of these tools and all its functionalities cannot be properly tested. You do not know what you are evaluating it for.

4. Costs and benefits.

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 terms of sustainable demolition and enables a director 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 business 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 demolition. In this second technique, it is important that business information related to previous traditional demolition projects is available and usable for this marginal cost-benefit analysis.

The analysis is about the additional costs associated with a circular process in relation to the additional revenues, as well as the minimization of all (transaction) costs evoked by circular demolition/dismantling, so that the benefits can be maximized, and the costs minimized. Both in business and social terms, if all calculations also include the social cost of Co_2 emissions.

A derived objective is to discover where things can be improved, but also for the use of other instruments, tools and methods and techniques, so that the social cost-benefit analysis step-by-step and improvement by improvement turns out positively in favor of Circular Demolition. In economic terms, we would also call it an analysis of all the transaction costs involved in a circular pilot compared to a classic pilot. We therefore need to identify all these (transaction) costs and benefits for each pilot.

To simplify the analysis, we have assumed that in the classical scenario there is only cost and the material yield can be set to 0. In addition, we have assumed that the organizational costs of both processes are equal, even though the knowledge deficit about circular demolition/disassembly will still temporarily cause differences in these organizational costs.

In a break-even analysis, the combination of equations 1 and 2 then looks like this:

3. $Sk + Dk = I + Sc + Dc + R - Mc$

Or in other words

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

Equation 4 states that if the material revenue is equal to the cost of inventory I, the additional cost of service of the demolition/dismantling company and the additional cost of deposit, processing and storage of the materials, circular and classical demolition have the same outcome in terms of costs and benefits.

The task now is to take a closer look at these costs and benefits, also considering what strategic actions can be taken to ensure that the costs of circular demolition decrease and the revenues from circular demolition increase.

In a marginal cost-benefit analysis, we would argue that:

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

That is, the change in revenue from circular demolition/dismantling should equal the (new) cost of inventory, the change in the cost of the demolition/dismantling company's services, and the change in the cost of processing, depositing and storing the materials. In this way, costs and choices can also be linked to each other, as in this way the alternative costs and benefits can be weighed against each other each time.

Each choice is therefore based on an analysis of the alternative costs (i.e. a (small) cost-benefit analysis). This is consistent with the foundations of economic science, which states that value can only be assigned 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 means. He is interested in the way different degrees of scarcity of different goods give rise to different ratios of valuation between them, and he is interested in the way in which changes in ends or changes in means-from the demand side or the supply side-affect these ratios. Economics is the science which studies human behavior as a relationship between ends and scarce means which have alternative uses.*"

Materials in or for buildings are alternative uses and scarce. Therefore, choices and (alternative) costs are always linked. Where no choice can be made regarding alternative uses, as with toxic substances or materials, a material also has no value. The Nobel laureate James Buchanan quotes Frank H. Knight on the principle surrounding this kind of cost:

"The opportunity cost notion is central. The cost of any alternative (simple or complex) chosen is the alternative that has to be given up; where there is no alternative to a given experience, no choice, there is no economic problem, and cost has no meaning. Economic cost, then, consists in the renunciation of some 'other' use of some resource or resource capacity in order to secure the benefit of the use to which it is actually devoted. The only general-cost theory which can be maintained will, after all, be that of alternative cost, ...

In the remainder of the analysis, we look at the following components:

a. Inventory

b. New services provided by the demolition/dismantling company

c. Costs of processing, depositing and storage

d. Revenues

So that we can gain insight into the operational manifestations of the costs and benefits. And with each component also being able to link quantitative data to each component. Data that comes from the operations of a pilot.

A linkage that allows us to gain insight into the various alternative costs and the choices we can make. Each part is equally important and brings different (transaction) costs and (new) revenues into focus that are worth investigating. Partly in the spirit of Ronald Coase and his most important articles The Problem of Social Costs (1960) and The Theory of the Firm (1937), based on which he called for the investigation of all transaction costs in a new process compared to older methods.

4.1. What costs can be identified?

When determining the costs within the social cost-benefit analysis, a distinction is made between the costs of inventory, dismantling, storage, and processing. We will explain these cost items below:

a. Inventory (I)

When making an inventory, we distinguish between three types of activities: a. the digital scan of a building, b. the detachability analysis and c. the materials inventory and registration. All three activities evoke work and therefore costs, which we need to know in completeness.

In addition, we look at these activities in the form of derived services from each other. That is, the digital scan of the building provides the preconditions for the removability analysis, and the materials inventory. And the removability analysis the depth of the materials inventory. We also need to determine the ways in which these forms of inventory can be easily organized and multiplied so that multiple individuals and organizations can perform these tasks and stakeholders are not hampered in this process by capacity constraints.

At its core, the materials inventory would only need to be required for those materials that can be put to alternative use. Those which the removability analysis has determined can also be technically reused. Whether or not they are economically reusable is related to the sum of all costs and benefits in the analysis. The removability analysis in any case saves the costs associated with the inventory of materials that are not reusable in any case, for example because of toxicity. Or for which it is almost certain, based on knowledge of the alternative costs of reuse, that these materials can only be reused with great losses. These are then skipped for the materials inventory and become part of a classic method of demolition. In operational terms, these come into play at the end of the demolition process, when previously all valuable elements of a building have been removed.

Because the alternative costs and benefits of materials are constantly changing, the removability expert will have to keep an eye on what her or his advice is based on. Whereby previously "red" marked parts of a building, i.e. not reusable, will nevertheless become "orange" (detailed research required), or even green (inventory, register and disassemble).

In terms of organizational costs of the inventory process, there are now always three different activities. Advisory and consulting organizations in the construction industry should be encouraged to be able to perform all three inventory activities jointly. This requires not only access or possession of tools, but also knowledge of materials, removability, and the use of tools for a digital scan and the registration of the materials in a digital materials database.

The costs for this capacity and competence development will need to be put into a picture in the total of all costs and benefits. Thus, for each pilot, we will need to meticulously list the costs of inventory.

b. New services provided by the demolition company (Sk-Sc).

In a circular process of demolition, the data related to the value of materials from a building determine to a large extent what services are requested from a demolition company. The materials inventory shapes the specifications in a quantitative sense. That is, which materials are to be removed from the building and in what way. The property owner also indicates what value of materials the demolition company must deliver after its services, so that waste and loss of value of materials is prevented as much as possible.

For each project or pilot project, it is important that the specifications for the assignment of the demolition company are drawn up in such a way that it is clearly indicated how the demolition company must deal with the materials and how it must deliver or transport the materials to the desired location. This can be deposit for low-grade processing, or to a depot (of the property owner or the party who has already purchased these materials, or to a processor) for high-grade processing.

There should always be a distinction in the direction of a demolition company in circular demolition between services and the value of the materials. In a classic demolition method, everything is lumped together, which means that a lot of information about the materials is lost. Information that can give materials a lot of value if it is done correctly. Therefore, a demolition company is only asked about their services and to separate these from the revenues of the materials and the costs associated with storing or processing the materials.

In this way, significant insight is gained into the cost-benefit analysis of each material for certain parts of the building, as well as the various costs of service associated with "harvesting" each material. It also reveals what costs are avoidable in the future if parts of a building are disassembled because of the choices made in constructing the building.

Transparency in costs can be obtained in several pilots, where different forms of service provided by a demolition company in the different options of circularity can be made visible.

c. Disposal, storage, and processing of the materials (Dk-Dc+R)

Relatively high costs in a traditional mode of demolition are evoked by the transportation costs to deposit the materials at a suitable waste site or at a low-grade materials processing site, as well as the processing of these materials. These costs should be identified in any project involving low-grade processing of materials. It is expected that these costs will increase, because there are increasingly higher demands on the processing of these materials, even in the case of low-grade processing. It is true, however, that these costs are often local in nature. Because higher costs of "disposal" reduce the relative costs of circular demolition, it is important that for strategic decision-making by any owner, these costs, including the social costs associated with them, are tracked over time.

This also applies to the processing costs of high value materials into new materials, or the direct reuse of materials products. These costs, which vary from transport, cleaning, storage, and processing into new products, will also have to be made transparent, so that they can be included in strategic decision-making processes relating to 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.

As a result of innovations (it is hoped), it will be possible to provide ever greater insight into the processing costs of low-grade and high-grade processing per material. This requires investments in the collection and presentation of data, which can also be supplemented with examples that can be used in other parts of the process of circular demolition. Here we are still at the beginning of a process, which will need to be further supplemented within Digital Deconstruction and beyond.

A final important subject about the strategic handling of materials is the materials in a building itself without being removed immediately. In a classical way of thinking about materials, these materials are not of alternative use and value. However, by attaching a property right to each material (blockchain registration) the property rights or options to the property rights can be given a different owner. This reinforces the strategic choice for the threefold division land, building, material, and can lead to new choices on how to deal with materials, because materials in buildings can then also get a different (specialized) owner, independent of the building. In this way the future reuse of materials can be organized in advance in the form of contracts, including the issue of liability if something should go 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 CO_2 emissions during production.

The above option fits with the strategy of real estate owners on circularity and can already be organized with the help of a digital materials database and blockchain technology. Within DDC, this will be able to lead to a different strategy, which will also become effective only after DDC. The costs and benefits of these activities belong to the cost of organization (O). The benefits of these activities will be visible beforehand in the revenues from the sale of materials from buildings, or the mode of circular construction of new buildings. Within DDC we will need to further shape and test this process using the "business model" for DDC.

In every pilot it is therefore important to map and analyze the costs of registering, transporting, and processing materials in various variants. In this way, important data will be gathered on the different costs of material processing in the various variants and the possibilities for cost reduction throughout the demolition and construction chain.

4.2. How can the effects and benefits be determined?

From the previous steps, it is known what the project alternative and the null alternative look like. Next, the effects of the project can be determined by looking at the differences between the project alternative and the base case. Effects are the consequences of the project or the policy for the various parties in society. Determining impacts involves two steps: 1. identifying impacts; 2. quantifying impacts. In the case of Circular Demolition, it involves identifying and recording those materials that are reusable. Directly or indirectly after processing. See also the previous paragraph under a. After the effects of the project have been determined, these effects must be converted to benefits.

Among the revenues from materials, we can distinguish two types of revenues in circular demolition. The first is the proceeds from the sale or internal reuse of the materials at fair value, i.e. at the sales value of comparable materials. The second concerns the revenue from a social or environmental perspective, because reusing the materials in an alternative form avoids the need to produce new materials of equal quality, as well as the Co2 emissions and use of scarce raw materials associated with this production.

In the process preceding the sale of these materials, a processing of these materials has taken place, the origin and quality of the materials is registered and traceable, so that issues arising from asymmetric information (the "lemons" issue) no longer arise. This means that in terms of costs, only those costs arise, which are related to the process of sale or alternative internal use of the materials, as well as the ability to convert the saved Co2 emissions into tradable emission rights and the sale of these rights.

Because the social revenue from saved CO2 cannot be converted into money now, the financial revenue will be equal to the value of the materials on a (digital) marketplace, which is comparable to primary materials, given the equal quality, minus the sales commissions of the digital marketplace. Or in other words:

Mc = Mb+Mm-P

Where:

Mc = the revenue from the sale of materials

Mb = the financial revenue from the sale of materials

Mm = the social revenue from the sale of materials

P = the commission on sales associated with the marketplace used in sales.

To track Mb, prices will need to be set for all materials. If these materials are not already traded directly, then the shadow price of the primary materials can also be used for this purpose. Given the pricing in local markets, averages for multiple markets will need to be compiled for the purpose of accurate data in a cost-benefit analysis.

To track Mm in monetary terms, the amount of Co2 saved from a material must be known. Then this saving, as well as the size of the materials, can be multiplied by the Co2/ton price of emission allowances, which is traded on the EEX. This emission price is currently around 80 euros per Co2 ton (April 8, 2022).

The commission on 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%.

To a strategic analysis of the costs and benefits of circular demolition vs classical demolition, the different selling prices of the most common materials in each environment need to be monitored on an ongoing basis if this strategy is to be implemented correctly as well. This also applies to the shadow prices about saved CO2, which can only really be included in the cost-benefit analysis if the rights to the saved CO2 can also be traded. Now they can only be named in technical and quantity terms.

As a final element in the strategic analysis of costs and benefits, it will be necessary to keep track of the costs of trading in reusable materials.

The above three paragraphs are action points to be kept track of and worked out in the local context, as are the variables in the previous paragraphs.

5. How can the balance of costs and benefits be determined and presented?

At this stage of the preparation of the cost-benefit analysis, information on costs and benefits is known. Since the costs and benefits are not realized at the same time ("the cost goes before the benefit"), it is important to plot the costs and benefits over time. Two value concepts are important here: Present value (CW) is the present monetary value of an amount that will be paid or received in the future.

The net present value (NPV) is the amount, obtained by subtracting the present value of the expected costs of an investment from the present value of the expected revenues. To assess the attractiveness of an investment, the net present value is always considered. When the net present value is greater than 0, the present value of the benefits exceeds the present value of the costs. It is then interesting from an economic point of view to invest in the project.

The result of the social cost-benefit analysis is an overview of the costs and benefits in the various months and years during the life span of the project. Costs and benefits fall at different points in time. For this reason, it is desirable to determine the present value of the costs and benefits. In this way, it is possible to compare costs and benefits. Translating future costs and/or benefits into present value is a technique known by the term discounting.

Since costs usually precede benefits, the use of a higher discount rate means that the balance of costs and benefits (net present value) is lower. This discount rate is set by the Dutch central government. In 2020 this discount rate was 2.25%.

A clear presentation of the results is desirable to quickly understand the results of the cost-benefit analysis. The quality of the results and thus the usefulness of the cost-benefit analysis is determined in which the effects are determined. Therefore, it is important to clearly indicate in the results how the effects were determined. It is also important to present all results in an unambiguous manner.

The determination of the effects and the benefits (expressed in monetary terms) is the most complex and the most crucial step in drawing up the cost-benefit analysis. The following definitions of effects and benefits are used. Effects are the consequences of the project for providers and demanders of the project services and other actors who experience advantages and disadvantages of the project. Benefits are equal to the amount (in Euros) that society is willing to pay for (allocate to) the realization of these effects.

The result of identifying the effects is that a final overview of the possible effects results, as shown in the table below, whereby effects can be placed under the following categories.

Actor Domain	Social effects	Individual effects
Social		
Economics		
Nature and environment		

The classification into the domains of social, nature, environment, and economy is also used in determining sustainability (people, planet, profit) and this classification is also used in the European Union guidelines for impact analyses.

6. Variants and risks.

In an ex-ante cost-benefit analysis, a prediction of the future is made and predictions are naturally surrounded by uncertainties. For example, effects may not be fully realized or costs may be higher than anticipated. A risk analysis can be used to identify these uncertainties. Uncertainties exist in any ex-ante evaluation (including cost-benefit analysis). The following uncertainties can occur:

- Decision uncertainties. These relate to the final choice for a project variant;

- Future uncertainties. These relate to uncertainties about future developments, such as the development of employment or the job security of the trained status holders.

- Knowledge uncertainties. Uncertainties caused by the lack of knowledge about, for example, quantities, prices, effects, and the like.

In the case study of circular construction and ditching, it is about future uncertainties and knowledge uncertainties, especially those related to prices of secondary materials.

When preparing the cost-benefit analysis, it is therefore important to take these uncertainties into account. The risk analysis provides a more realistic picture of the level of costs and benefits. The cost-benefit analysis also provides vital information for the risk analysis because it gives a quantitative picture of the level of risks. The risk analysis consists of the following steps:

1. Map the uncertainties (identify).

2. Determine the extent to which these uncertainties affect the cost-benefit analysis.

3. Incorporate these uncertainties into the cost-benefit analysis. Depending on the uncertainty, there are different ways to deal with these uncertainties.

How to deal with uncertainties

Decision uncertainties	*Analyse the different project variants*
Future uncertainties	
- *Macro-economic uncertainties*	*Make a scenario analysis*
	Use a risk fee at the basic interest rate
- *Project specific uncertainties*	*Correct specific costs and benefits for project specific uncertainties*
Knowledge uncertainties	*Make a sensitivity analysis*

For knowledge uncertainties, sensitivity analysis is an important tool. In the case of Circular Demolition, this concerns sensitivities related to the prices of the underlying (additional) services, as well as the prices of materials in an alternative mode of use.

The desired cycle of circular use of materials currently exists for only a few materials, such as metals. For the remaining materials, there is no cycle, because after the materials are used in a building, most of the materials are landfilled, incinerated, or reused in a low-grade manner after demolition (no disassembly). For these materials, it is economically cheaper to buy new materials than to put existing materials through the operations of the cycle. However, for more and more materials, this balance is beginning to shift, spurred by price increases for new materials, as well as the pricing of the social costs related to the destruction of existing materials. This is happening along the avenues of liability and Co2 prices for making alternative new materials (ETS rights).

Examples from waste processors of building materials show, that waste is increasingly becoming a raw material, because after sorting and cleaning of the materials, new raw materials that are competitive with primary raw materials emerge. Ditto for products. Not because these secondary raw materials have now become cheaper, but because the cost of primary raw materials is skyrocketing. 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 building stakeholders as possible an integral insight into their own derived revenue model, which often includes part of the entire cycle. This compares to a classical way of building and demolishing, in which the disappearance of materials is the issue.

A cycle that not only has the physical flows of the materials as its basis, 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 in this way continuously connected to each other in an enforceable way. In the traditional way, this legal infrastructure is absent, which results in waste being the norm, because the cycle can never be closed due to the loose connection between stakeholders.

A social cost-benefit analysis about Circular Construction and Demolition depicts all aspects of the cycle with all stakeholders, maps the costs and benefits of each part of the cycle using examples and cases, but will also have to show, how the action of one stakeholder improves or can improve the business model of the other stakeholder, and then benefits itself.

Examples:

1. Inventory of materials improves the transparency of the materials, especially about quantity (detachability) 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.

2. The clean delivery of materials to a processor increases the costs of the demolisher or dismantling company, but leads to higher quality materials when processed. And so the processor will earn more, or have lower costs, for landfill or incineration. The processor will share this higher gross margin with the dismantler for his or her preliminary work.

3. Making a 3d scan during the inventory process reduces the cost of the removability analysis for a building, because 3d data can be read directly into a BIM model for this analysis. This then lowers the integral cost of the inventory, making the business case for the loop in total beat faster.

The cycle of materials can be improved again and again with similar examples, where a cost-benefit analysis aims to share and secure 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 do a 3d scan at the front end of the cycle, how does that lead to a cost savings for the processor's buyer, who in turn turns it into new raw materials or products with the right quality.

Or, conversely, if the processor starts to pay for the purchase of waste, this means a direct incentive for the storage of materials, as well as the dismantler 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 materials". The cost-benefit analysis thus plays into the prevention of "system failure", or insufficient coordination of value-added actions of successive chain partners, which negatively affects or even destroys the business model in the next of the chain. Inventory makes those costs, benefits, and related actions transparent, so that parties in the chain can better agree on quality, as well as the remuneration of their extra part in the chain.

The demolisher or dismantling company will then have 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 manager" of the circuit to start greatly reducing the cost of inventories and storage with a quick delivery to the processor, who will make granules from them, for example, rather than weighing storage costs against the cost of landfill or incineration. The latter cost of waste, including its social cost, will then disappear, or at least drastically reduce.

In this closed-loop approach we can then not only determine the additional costs and additional benefits of an extra step for the next link on the road to a closed loop, but also gain insight into the nature of a disruption. After all, as the case study 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 on the "titles/tokens" for materials

These barriers may come up in the cases and should be mapped with the descriptions for example in a handbook. They then appear on the "funds list", to which funds from governments or resources from investors can be linked

Three lines/scenarios are provided for the search for information and sources for further analyses:

1. Mapping the direct visible costs of all operations in the cycle (classical or circular) to be expressed in euros per 1,000 kilograms of materials, or a limited number of materials.

2. Mapping efficiency strokes of investments and innovation in one part of the cycle onto the other parts of the cycle on the way from classic to circular (interventions). For example, from inventory to demolition/dismantling, or from processing to the purchase of raw materials. Each time expressed in euros per 1000 kilos of materials, or a limited number of materials. Each intervention will be described in the relevant section in a handbook provided with the cost-benefit analysis. A list will be made of types of interventions through the whole cycle, ordered by link-to-shift effect.

3. Mapping the effects of "tipping points". That is, of events that lead to closing the loop rather than disrupting it. For example: earning from the delivery of waste, rather than paying for it. Or setting up a marketplace for trading rights to materials. Tipping-points result in major behavioral changes of all

stakeholders and subsequently cause major disruptions in the development of a market. Each "tipping-point" belongs to a certain link in the cycle, which is described in the handbook.

7. Concluding remark

In his 1937 article "The Theory of the Firm", Ronald Coase called on everyone to investigate further the transaction costs of a firm in its relationships with customers, suppliers, personnel, and organization compared to the costs of separate contracts that anyone can enter with each other for each transaction they make. For example, for every hour of labor instead of a longer-term employment contract, etc. And to take this up case by case.

The comparison between a classical method of demolition and circular demolition raises a similar thought. Let's put all (transaction) costs of both alternatives next to each other and compare them for each pilot or case, so that on the basis of an analysis of these differences we can also find out what causes these differences and with what investments, forms of regulation, the different costs and benefits can be represented in such a way that circular construction and demolition clearly have added value. The pilots within DDC lay a foundation for this if the various figures relating to costs and benefits can be made transparent for each part of the process of circular demolition.