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Target Sustainability Design - Application of sustainability to the target value design method

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ABSTRACT

Tight investment budgets and high demands on sustainability lead to the classic conflict of objectives in projects. Especially in Target Value Design (TVD), the focus lays strongly on cost compliance. As a result, environmental goals have little chance of being achieved if they are viewed as an adjunct to functionality and quality. Even short-term consideration of LCA factors or energy efficiency in the early stages of design cannot resolve the trade-off between economic and environmental goals. Consequently, it is unclear how to make decisions when environmental and economic goals appear to be incompatible. It is also unclear how to incorporate social factors into TVD. *Target Sustainability Design* (TSD) was developed to address these issues. To do this, TVD has been broken down into its components and combined with the factors of strong sustainability in such a way that environmental and social goals become an integral part of the TSD methodology. The goals of all three dimensions of sustainability are not at odds with each other when using the TSD method, but can only be achieved together. This paper presents the composition of TSD and illustrates how it works with a case study.

Keywords: lean construction, sustainability, target value design, circular construction, decision making

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1 Introduction

At the latest with the Rio+20 Conference in New York in 2012 and the United Nations General Assembly on September 25, 2015, where the 17 Sustainable Development Goals were bindingly adopted as the 2030 Agenda, it has become clear around the world that focusing solely on the economic dimension is not enough to ensure lasting global prosperity. In addition to ending poverty and inequality, strategies are needed to improve health and education, while combating climate change and preserving oceans and forests. The preamble to the 2030 Agenda makes clear that the economic dimension is integral and inseparable from the social and environmental dimensions ([United Nations General Assembly, 2015](#)).

Construction projects often have very limited budgets. At the same time, environmental sustainability requirements must be met. This often results in a classic trade-off, as meeting environmental goals is perceived as an additional cost factor that strains the budget. In addition to the environmental and economic dimensions, social sustainability goals are often considered only in terms of protecting the health of the people who build. A life-cycle consideration of the social needs of all stakeholders is very limited ([Kordi et al., 2021](#)).

To ensure that cost targets are met, especially in the context of Integrated Project Delivery (IPD), the method of Target Value Design (TVD) is used, since the application of TVD can demonstrably increase cost target compliance (Do et al., 2014). If we look at the factors of the TVD, we see that targets are defined only for the economic dimension and that the social and environmental dimensions are not taken into account. This prioritization of cost compliance results in the subordination or partial omission of environmental and, where available, social sustainability goals.

The aim is therefore to further develop TVD into Target Sustainability Design (TSD) in order to transform the antinomic target relationship between environmental and economic targets into a complementary target relationship in the sense of a holistic view. At the same time, social goals are to be included in the value determination. The aim of this further development is to establish a comprehensive system for taking all sustainability dimensions into account in order to support holistic decisions.

2 Methodology

The motivation for the development of the TSD began with the participation of the authors in a planning team in an IPD tendering process. In this German public construction project, the client set tight cost targets that were to be achieved with the help of the TVD method. At the same time, ambitious environmental sustainability targets were set. The conflict of goals between environment and economy could not be clarified in the bidding phase. However, the conflict of objectives should not be regarded as an isolated case, but is systemic, since investments in environmental measures that go beyond legal requirements regularly result in increased manufacturing costs. Accordingly, a systematic solution for overcoming the trade-off has been sought. This paper presents the development and a first validation of the TSD.

Within the scope of a literature research, it is first clarified which approaches already exist for the solution of the target conflict. Here it can be determined that there are approaches that promote the consideration and implementation of environmental factors, but do not solve the trade-off and do not include consideration of social factors.

As a way to overcome the conflict of objectives, a fusion of TVD and the strong sustainability is done in the development of the TSD. For this purpose, the TVD and strong sustainability were decomposed into their individual components and recombined in such a way that manufacturing costs cannot work against environmental goals. Additionally, social factors are integrated in such a way that they can be considered in the value determination. This concept of TSD was first presented by the authors at the German Lean Construction Institute (GLCI) conference in October 2021.

In order to validate the effectiveness of the concept, the formula of the TSD was subsequently run through using a case study. The results of the case study are published for the first time with this paper.

Since further dissemination of the TSD in non-German-speaking countries is desired, the paper has been translated into English and should be available in both languages. The authors used AI-based translation software (deepL and GoogleTranslate) to support the translation. The review was done from the English version.

3 Literature review

The aim of the literature review is to clarify whether there are approaches that take environmental and social sustainability aspects into account in decision-making processes in the construction industry, especially in TVD. The aim is to clarify whether a solution to the conflict between cost and environmental sustainability aspects has already been found.

For the unsystematic literature search, the search engines researchgate.net and scholar.google.com and the research portal of the Swiss national library platform swisscovery were used. Combinations of the English and German keywords "sustainability", "sustainable", "target value design", "decision making", "Entscheidungsfindung", "Nachhaltigkeit" and "nachhaltig" were used. After this, additional sources were searched for using the snowball principle. During the search it was found that only little relevant literature could be found. The sources most pertinent to the topic are briefly presented here to illustrate the gap that the TSD aims to fill.

A graphical approach was developed by De Benedetto and Klemeš (2009), which shows the relationship between 5 factors of a Life Cycle Assessment (LCA) as the base of a 5-sided pyramid with the cost dimension as the height of the pyramid. This approach was developed for production processes without considering the use phase or the post-use phase. The CO₂ footprint, water footprint, energy footprint, emission footprint and occupational safety were chosen as the 5 elements of the pyramid footprint. The graphical representation of the volumes can simplify the decision making between different variants. Since the approach was set up in a general way, no construction-specific aspects, such as urban mine, or social aspects outside of workers safety during production are integrated ([De Benedetto & Klemeš, 2009](#)).

Russel-Smith et al. (2015) pioneered the integration of environmental targets into TVD. To enable a quick simplified LCA analysis as a basis for decision making, a Microsoft Excel-based software tool was developed. The software tool allows LCA analysis narrowed down to 4 impact categories for the planning phase of a building. The target values of global warming potential and primary energy demand, with reference to the Intergovernmental Panel on Climate Change (IPCC), drinking water with reference to the US Energy Policy Act of 2005 and ozone depletion potential based on the 1997 Montreal Protocol were set below the respective limits and tracked in the planning process. In a study conducted with students, it was found that the continuous comparison of planning variants with a quantitative target value led to more environmental sustainable solutions than those of the control group with only qualitative requirements. The LCA analyses here refer to construction, and the effects of the use and post-use phases are not taken into account. Furthermore, it remains

unclear how decisions can be made in the case of conflicts between investment costs and environmental sustainability goals ([Russell-Smith et al., 2015](#)).

In 2018, Hamdan et al. (2018) attempted to implement operational phase energy consumption into the TVD using a physical-mathematical formula-based approach. He presents a formula to relate design functionality, usage-based energy consumption, and building envelope insulation values. The development of the formula is not described in the paper and is accordingly difficult to follow ([Hamdan et al., 2018](#)).

Silveira and Alves (2018) found in their literature and interview study that TVD-inspired projects in California, USA were better able to achieve environmental friendly sustainability goals than non-TVD-inspired projects. It was possible to work out that the early and close cooperation with the operators and users increases energy efficiency, since the use in the use phase can be better understood and planned accordingly ([Silveira & Alves, 2018](#)).

Roberts et al. (2020) recorded in a systematic literature review that LCA is typically not integrated into the planning and, as documentation of an actual state, does not enable any improvement of buildings. However, it was found that the implementation of LCA in the early planning phases is a success factor for the development of more environmental friendly solutions. The construction-related effects as well as the use-related effects are relevant for achieving the Net-Zero 2050 goal. A combined consideration of LCA and life cycle costs (LCC) helps to find a suitable solution from an economic and environmental point of view and to make decisions. The result is that the depth of LCA determinations should be chosen appropriately depending on the planning status. Software-supported solutions, regardless of whether they are BIM-integrated, parametric or other tools, can deliver fast and short-cycle LCAs, but knowledge of the key influencing factors for the evaluation of LCA results during use is important in order to be able to make competent decisions ([Roberts et al., 2020](#)).

The literature review showed that approaches for the implementation of environmental targets in the TVD process leads to improved results regarding the environmental performance of buildings. However, the question of how conflicts between economic and environmental targets can be resolved remains unanswered. It is also open how social factors and the value of the urban mine can be considered in the TVD.

4 Characteristics of the Target Value Design

TVD is a method that includes factors as metrics for the evaluation on the one hand and a process designed for transparency for tracking and ensuring the achievement of objectives on the other. The basis of TVD lies in the target costing method, which is used in the manufacturing industry with the intention of using costs as a target criterion and thus input variable for planning ([Ballard, 2006](#)).

The value in the TVD is described by the relation of the two factors cost and scope. Within the TVD process, the target factors are then formed from the factors. Accordingly, this results in target cost, target scope and target value, which are tracked in the process.

The TVD method requires cooperative and co-creative participation of all stakeholders throughout the process. In particular, it promotes the development of innovative approaches to meeting target costs and scope within the framework of transparent cost planning ([Zimina et al., 2012](#)). For this purpose, the project team is divided into interdisciplinary working groups called *cluster groups* without consideration of the originating companies according to the maxim *best-for-project*. Accordingly, representatives of the client as well as of the operators and users can also become part of cluster groups if this is appropriate for the project. In this way, each cluster group can develop the best technical and functional solutions for its working area and make decisions. Decisions and tasks that need to be made or completed for multiple clusters are managed by the core group, which consists of representatives of the key contractors (planners as well as implementers) and the customer (clients as well as users and operators) ([Do et al., 2015](#)).

4.1 The factors and the equation of the TVD

The factors by which the planning or the project is measured are compliant with the cost target as well as the required scope, described by functionality and quality. Both are input variables for planning in TVD, and not a result of planning. Thus, as planning criteria, they become a characteristic of the deliverable and planning quality is measured accordingly against these factors ([Mossman et al., 2013](#)).

Accordingly, at the start of the project, a feasibility study is conducted to establish the factors in detail so that there is clarity among all project participants regarding the ends and constraints and a common understanding of the ordering party's business case is formed among all stakeholders ([Ballard, 2006](#)).

Factor Target Scope

The definition of the target scope initially includes clarification of the ends and the means. The ends describe the functional requirements with the purpose of use and the desired values. The means capture the quality requirements of the building and the usage requirements ([Ballard, 2006](#)).

Consequently, the TVD first examines what ends are to be achieved with the project and what the use of the building requires. These questions are to be based on the functionality in terms of the intended use and on the desired quality based on the intended purpose. Accordingly, the questions to be answered are "What ends are to be achieved by the project? What does the use require?"

As part of the project target definition, the project team clarifies what the usage needs are instead of what the customers think is needed to meet the demand.

For example, if a customer needs a roof, the question arises as to what this protection will be used for. It may be that a transportable lightweight system is the appropriate solution for the function. However, it may be that a permanent structure is required. Once it has been clarified why something is desired, and thus which functions are to be fulfilled, the required quality and the market price can be determined.

Factor Target Cost

The target cost is derived from the system of target costing, in which the market price is determined first, see [Figure 1](#). The market price is characterized by what customers are willing to pay for a particular product. This reflects the relationship between supply and demand. In addition, a key determinant of the market price is the functionality desired by customers in combination with the required quality ([Mossman et al., 2013](#)).

$$\begin{aligned} \text{market price (fixed determined 1st)} - \text{target profit} &= \text{production cost} \\ \text{production cost} - \text{contingency} &= \text{allowable cost} \\ \text{allowable cost} \geq \text{expected cost} &\geq \text{target cost} \end{aligned}$$

Figure 1
Derivation of target costs from market price

In order to determine the target costs, first the desired profit is deducted from the market price leaving the production costs ([Tillmann et al., 2017](#)).

A budget for project risks (contingency) is then deducted from the production costs, resulting in the allowable cost. In a study by Berkeley University, it was found that projects carried out with TVD require a lower budget for project risks than conventional project delivery models ([Do et al., 2014](#)).

Within a feasibility study, it must be checked whether the allowable costs are below the expected costs. If this is the case, it can be assumed that the scope and costs are consistent. The project team agrees on the target cost on this basis. Ambitious target costs are often agreed upon to stimulate innovation ([Ballard, 2011](#)).

The target costs are divided into clusters, usually component-related, for further processing of the project. The division is made available transparently in a target cost model to all project participants ([Ballard & Morris, 2010](#)). Since the classification is based on assumptions, the values are not to be considered as possible costs to be consumed, but as maximum possible costs. Unused cost resources in one cluster, are to be made available to other clusters, which were too tight in the initial classification. It is therefore imperative to avoid silo thinking ([Do et al., 2015](#)).

Constraints

The constraints of a project lie in the resources available for its realization. In TVD, these are - based on target costing - the costs. In the feasibility study, the constraints are clarified jointly by all participants, so that the following cardinal rule is jointly established: "the Target Cost cannot be exceeded" ([Ballard, 2006](#)).

In the course of the further development of the TVD, the focus on resources was sharpened and the cardinal rule was expanded in 2011 to include the factor of time to "cost and schedule targets cannot be exceeded"

(Ballard, 2011). This extension is logical regarding the overall view of the business case, since a delayed provision of the construction triggers consequential costs, such as loss of rent, delayed production, financing costs, etc. Since the scheduling factors are related to costs, the term *cost* is used in this report for simplification.

As part of the expansion, it was also added to the cardinal rule that only ordering parties may approve changes to the scope, quality, cost, or schedule factors.

However, the cardinal rule does not mean that the target cost alone is above everything. When applying the rule, the target scope must also be considered, which must not be unfulfilled. Thus, if there is a threat of cost overruns in one cluster, these must be offset by free costs from another cluster without reducing the scope. The provision of free costs is made possible by the exclusion of additional services. This means that the budgeted target costs of a cluster may not be consumed unnecessarily, but the free budget must be made available to other clusters accordingly. Indeed, the target value can only be achieved if the target scope is implemented within the target costs (Do et al., 2015).

In terms of process, the rule means that the transition from design to construction must be managed in such a way that the target costs are not exceeded. This is only possible if there is close cooperation and co-creation between the client, design, and executing parties throughout the project and if everyone shares an understanding of the ends set throughout the project.

Equation of the Target Value Design

Ratios of factors to each other can be well described in mathematical formulas, even if no mathematical result can be obtained. The ratios of the factors in the TVD are represented accordingly by means of a fraction.

If the factors are transferred into an equation using the cardinal rule, the target value is the quotient of target scope and target cost, see Figure 2. The target scope is in the numerator and the target costs are in the denominator. This means that the larger the cost becomes, the smaller the value becomes. Similarly, the smaller the scope becomes, the lower the value becomes. Thus, the value is greatest when the scope is realized at the lowest cost.

$$\text{Value} = \frac{\text{scope}}{\text{cost}} = \frac{\text{functionality} + \text{quality}}{\text{cost}}$$

Figure 2
Equation of the value in TVD

4.2 Systematics of the TVD process

In addition to the factors, the TVD is characterized by a co-creative process. Beginning with project initialization and continuing through commissioning, this process encompasses the entire project lifecycle and is divided into three steps: ([Ballard & Morris, 2010](#))

1. Set targets
2. Design to Targets
3. Build to Targets

An essential characteristic of the TVD is that the start of each step can only take place when feedback to the previous step has taken place. This involves a comparison with the previously defined targets. Only when these targets have been achieved the next step may be started. This feedback ensures that possible deviations from the objectives are presented transparently and that a way of dealing with them can be found. Accordingly, the transition from one step to the next must be managed consciously.

In 2015, the term Target Value Design was supplemented by the term Target Value Delivery to emphasize that TVD is also applied in the construction process after the planning phase. Accordingly, both terms can be used synonymously, but it is appropriate to use the term Target Value Delivery when talking about the execution phase in a focused way ([Do et al., 2015](#)).

TVD Step 1

In step 1 Set Targets, the ends of the client stakeholders are established and validated within the framework of a feasibility study.

The ordering parties have a project idea and define the value they would like to receive by carrying out the project by establishing the scope and the possible costs (allowable cost).

The ordering parties commission a core group consisting of representatives of the main project stakeholders to conduct a feasibility study to review the scope and costs and define the target scope. For this purpose, first the desired scope is questioned with regard to the ends (Why?) and the means (What?) and second the target scope is defined by a description of the functionality and quality. At the same time, the costs incurred for the defined target scope are reviewed. For this purpose, the costs are considered adjusted for profit and risk. The core group compares the expected costs and the target scope with the project idea and presents this result to the client ([Ballard, 2006](#)).

In case of deviations of the result from the project idea, the client must decide whether the project idea can be adjusted or whether this project has to be terminated and, if necessary, a new project with a new project idea has to be initiated.

If the project idea can be adapted, or the result of the feasibility study corresponds to the project idea, the scope and costs are divided into clusters by the Core Group.

Based on this information, the ordering party can decide whether to start the next step.

TVD step 2

With the start of step 2 - Design to Target, the project team is expanded so that a Cluster Group can be set up for each cluster. Each Cluster Group is interdisciplinary to ensure comprehensive content and cost consideration within each cluster. The clusters develop solution proposals step by step in iteration cycles, which must be within the allocated costs. Cost control is carried out by the cluster group itself. If the costs cannot be met, variants must be developed until a suitable solution is found. At the end of a cycle, the solutions and variants of the various clusters are presented to the core group, which then determines whether the objectives can be achieved with the sum of the results.

Budget shifts between the clusters can also take place during this comparison, since free costs are made available to other clusters here, which could only meet the allocated costs by reducing the scope. This gives the client the opportunity to choose between the variants that come closest to the project idea in total. If no solution corresponds to the project idea and the project idea cannot be adapted to the planning, the client has the option to terminate the project.

With the decision as to which variants are to be processed further, the cluster groups begin the next iteration cycle until the planning is ready for execution. The importance of the division into project cycles for the course of the project should not be underestimated since important decisions are linked to this.

The cycle prior to the submission of the building application is of particular importance, as essential building features are also officially defined and approved with the building permit. Adjustments relevant to approval are associated with additional costs and scheduling consequences; accordingly, these topics should be clarified and decided beforehand.

Also, the cycle before the decision to start construction, should be given high attention, because with the start of construction, the cost of the project increases significantly and a project abandonment during the execution phase has much higher consequences. Special care must be taken when different clusters are able to submit design ready for execution at different times and for some the start of execution is released earlier. For this early release, it must be ensured that no impact from other clusters is expected on the planning of the clusters to be released. It is imperative to avoid that adjustments are necessary after the start of execution due to the results of other clusters, as these would cause a disruption in the project progress.

5 Models of sustainability

In order to be able to implement all sustainability dimensions in the TVD, they are first examined in more detail. To this end, the model of weak sustainability is first compared with the model of strong sustainability. Here, the different understanding of the respective relationship or weighting of the dimensions among each other is shown. (ref?) shows typical representations of the weak and strong sustainability models.

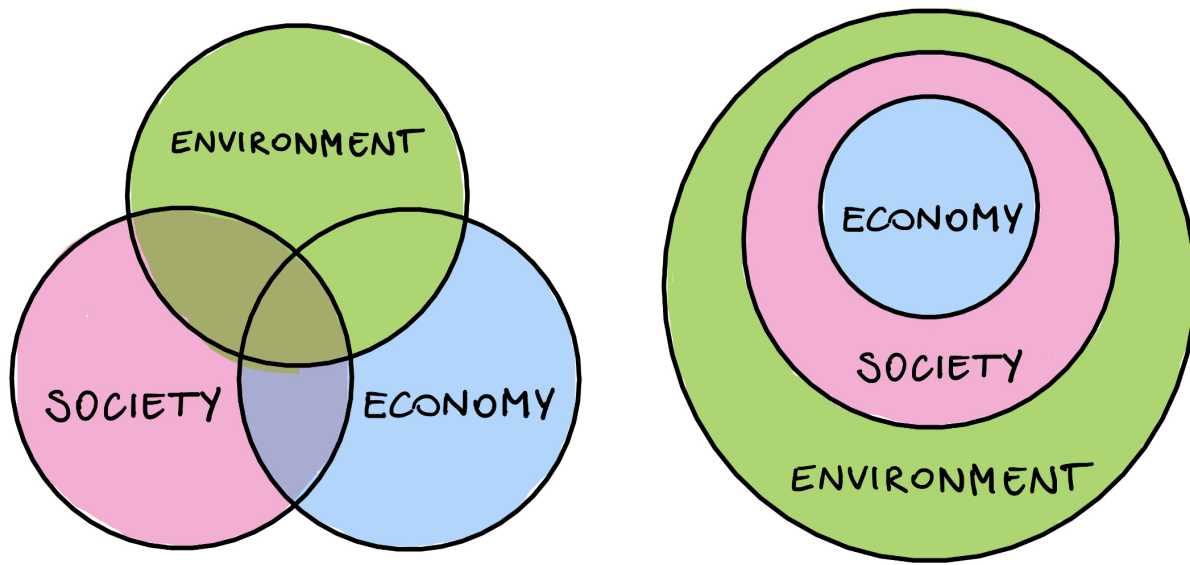


Figure 3
weak sustainability and strong sustainability

5.1 Model of weak sustainability

The weak sustainability model includes the dimensions of economy, society and environment. Seen holistically, everything seems to be included, but it is questionable whether this actually brings sustainability, since the dimensions as pillars stand side by side on an equal footing. The model of weak sustainability is therefore also referred to as the 3-pillar model. Each pillar is considered to be of equal importance and equal status, since in this model all pillars are considered as one overall capital value. Ideally, this capital value should be preserved or ideally increased for future generations. This relationship construct means that one can be compensated for by the other. Economy can therefore compensate for environmental deficits with the result that no actually sustainable action arises (Neumayer, 2012).

5.2 Model of strong sustainability

The 2030 Agenda's call for global sustainable development makes it clear that there can be no balancing of between the economic, social and environmental dimensions (United Nations General Assembly, 2015). Therefore, they must be considered in their relationship and dependence on each other.

The model of strong sustainability describes the environment as the basis of all our economic activity, as it cannot be balanced by economic or social capital ([Neumayer, 2012](#)). Only in an intact environment a stable society can develop. This can be seen in regions where the population is dwindling because it is affected by environmental disasters. In turn, a functioning economy can only be established in a stable society. This can be seen in countries that are, for example, affected by strong migration because of political unrest and/or corruption.

In strong sustainability, the environmental dimension has priority due to the dependencies presented. Therefore, it is also called the priority model.

6 Combination of the TVD with the strong sustainability to the TSD

Strong sustainability demands a change in thinking to the effect that environmental factors are the basis of every society and economy. Accordingly, the TVD equation must be supplemented so that social factors are considered and environmental factors cannot be offset by economic factors.

In the following, the TSD equation is presented first, then the factors are explained in detail and the effects on the TVD process are presented.

6.1 Equation of the Target Sustainability Design

In the denominator of the equation in the TVD are the costs, which with this positioning have a large leverage on the value. If environmental factors were now only included in the numerator in the scope, low costs could compensate for deficits in the environmental or social dimension. As a result, only weak sustainability would be implemented.

In strong sustainability, however, there must not be the possibility of compensating environmental factors by low costs, as this would violate the basic principle of strong sustainability. Accordingly, environmental factors must be added to the denominator. Monetary expenditures and the use of the earth can be classified holistically as resource expenditures.

In addition to the intended use for the ordering parties, every construction project also has an impact on society. Accordingly, social factors must be placed in the numerator alongside functionality and quality. The sum of these factors forms a holistic added value, which is decisive for determining how much resource expenditure customers are willing to invest. The equation of the TSD is shown in Figure 4.

$$\text{sustainable value} = \frac{(\text{functionality} + \text{quality}) * \text{society}}{\text{costs} + \text{environment}} = \frac{\text{Added value}}{\text{Resource expenditure}}$$

Figure 4
Sustainable value in TSD

As a result, it can be stated that the economic and environmental factors cannot be played off against each other, as they are considered together in the denominator. By adding social factors to the numerator, these can also positively influence the sustainable value.

Accordingly, the following applies to the assessment of sustainable value: the higher the added value and the lower the resource expenditure, the higher the sustainable value.

6.2 Sustainability factors in the TSD

If the goals of sustainable development are taken seriously, the model of strong sustainability must be anchored in every project as an integrative component of project management. Accordingly, all dimensions must be considered. For the TSD, the dimensions are transferred as factors into the TVD equation for this purpose.

In the aforementioned form, the equation is still too abstract to be applied in projects. The factors must be broken down accordingly.

In addition to the functionalities and qualities defined in the scope, social aspects were added to the numerator. This includes any factors that have a positive value for all stakeholders and not just for the ordering parties. In the denominator, the costs and environment are translated into life cycle costs, environmental impact costs, and urban mine. Accordingly, life cycle costs are used instead of construction costs to capture operating costs in addition to construction costs. In this way, the short-term cost consideration based solely on the period of construction is extended to the entire life cycle of a building. By taking into account the environmental impact costs, which are borne by society, the cost consideration, which usually is solely oriented towards the client in terms of business economics, becomes oriented towards the societal economy. Overall, this means a significant expansion of the scope of cost consideration.

Regarding the environmental impact costs, this first form of the TSD considers the climate impact of various climate-damaging emissions in the form of CO₂ equivalent and quantifies them in monetary terms. It is important here to assume a CO₂ price that is as realistic or fair as possible.

Other environmental impact costs, such as those arising from the loss of biodiversity or potable freshwater, are also relevant, but have not yet been included in the equation since they cannot be sufficiently quantified in monetary terms at present. However, their consideration is basically envisaged here.

With this expansion of factors in the denominator, it appears that sustainable factors are loading the equation. However, sustainable action also contributes to achieve the target, as the denominator considers the value of the structure as a raw material store (urban mine), thus making the denominator smaller.

Adding life-cycle-cost, environmental impact costs, and urban mine to the equation, allows for a holistic view of resource expenditure.

$$\text{target sustainability} = \frac{(\text{functionality} + \text{quality}) * \text{social aspects}}{\text{life cycle costs} + \text{environmental impact costs} - \text{urban mine}}$$

[€/LC * LC]
[CO₂e * €/tCO₂]
[€]

Figure 5
Factors in the equation of the TSD

With regard to the environmental costs, in this first form of the TSD, the climate impact of various climate-damaging emissions in the form of CO₂ equivalents is considered and quantified in monetary terms. The decision to initially only consider climate impact is due to the fact that the global urgency of implementing climate protection is a basic requirement for the preservation of habitats. It is important here that a CO₂ price that is as realistic as possible and appropriate for generations is assumed.

Other environmental costs such as the loss of biodiversity or potable fresh water are also relevant but have not yet been included in the equation because the monetary quantification is currently not sufficiently reliable. In principle, however, their consideration is provided here.

An approach for the monetarization of further environmental impact costs can be based on the example of the Netherlands, where environmental impact costs are monetarized on the basis of life cycle assessments and referred to as shadow costs. The shadow costs contain 11 impact categories and are expressed in €/kg eq. Software tools can be used to express these costs in € per year of useful life and m² of gross floor area (€/year/m²BGF). Even if the cost approach is given by regulatory side, this approach shows that monetization of the factors allows easy comparability ([de Klijn-Chevalerias & Javed, 2017](#)).

However, the monetary value of an environmental impact plays an important role, especially with regard to intergenerational equity, when it comes to comparison with monetary amounts. Accordingly, a clear understanding of the background to monetization is required. Other impact categories should therefore additionally be taken into account when formulating the objectives of a project. Future extensions of the TSD equation to other environmental impact costs are envisaged and can be recorded in the same way as the system.

6.3 Social aspects

Every building has an impact on society through its construction and existence. Investment decisions that aim to achieve the greatest possible positive social impact with minimal negative effects are referred to as *social*

impact investing. Here, impact targets are set for various social aspects ([Institut für Corporate Governance in der deutschen Immobilienwirtschaft e.V., 2021](#)).

If metrics are set for the impact targets of the social aspects, the achievement of the targets can be measured against them. In the TSD, the social impact is referred to as social benefit. If all metrically recorded social requirements are completely fulfilled, there is a social benefit of 1 or 100%. Since the impact radius of a building can have different characteristics, the metrics and the associated evaluation methods and assessment standards can also vary.

The social acceptance of a building project in a community, a district or a neighborhood is highly relevant. This can be ensured through an appropriate building culture by means of architectural competitions with the integration of all stakeholders. However, participation is not only desired during project initialization, but is also an important factor for social acceptance during the planning, execution and operation phases. It can be determined by means of suitable surveys at various points in the project.

Users want buildings in which they feel comfortable, so comfort also plays an important role. This can be defined and made measurable, for example, by specifying daylight qualities, air quality etc.

The possibility of participation and appropriate mobility is reflected in factors such as barrier-free accessibility, mobility, local supply, or local recreation.

In addition to the UN's 17 Sustainable Development Goals, green building certification systems offer comprehensive lists of social factors, of which the weighting can be incorporated into the projects as metrics in consultation with the clients, users, and other stakeholders. It must be considered that the stakeholders are not only those involved in the project, but that any person who is affected or feels affected by a construction project can be a stakeholder. Since buildings also have an impact on future generations, their interests must also be considered.

6.4 Economic aspects - life cycle cost

Instead of production costs, life cycle costs (LCC) are to be considered in the TSD. The reason is that, in addition to the construction costs, they also include the operating costs, which represent by far the largest part of the costs in the life cycle of a building.

Life cycle costs comprise all costs over the lifetime of a structure. To date, however, there is no uniform or standardized methodology in Europe for calculating them. According to GEFMA, life cycle costs essentially include the following ([GEFMA/IFMA, 2010](#)):

1. Project development and planning costs
2. Construction costs
3. Operating and usage costs

- Supply and disposal costs (water, fuels, energy, wastewater)
 - Cleaning and maintenance costs
 - Operating, maintenance and repair costs
 - Maintenance costs
 - Property management and administration costs
4. Conversion and renovation costs
 5. Costs for disassembly and recycling

Benchmarks have been developed by the German certification systems for the assessment of life cycle costs. These are limited to purely building-related costs and currently do not contain planning or demolition costs. Nevertheless, the benchmarks of certification systems can be used when setting a target value. However, environmental impact costs must also be considered. More ambitious targets, such as plus-energy buildings that feed energy into the overall system instead of consuming energy in the life cycle, increase the value of the building, since energy generation has a mitigating effect on resource consumption.

6.5 Environmental aspects - Environmental impact costs / life cycle assessment

Environmental impact costs or environmental costs are the costs resulting of environmental pollution, which need to be borne by society. These include, among other things, the expenses to pay for environment-related damage to health or materials, e.g. as a result of flooding, as well as damage to ecosystems, such as the loss of biodiversity or potable freshwater ([Umweltbundesamt, 2021](#)). The basis for determining environmental impact costs is a life cycle assessment. Based on the LCA, emissions can be converted to cash values through monetization.

The environmental impact costs due to climate change, so called climate cost, can be well described in monetary terms using a CO₂ price. To account for all greenhouse gases, their global warming potential is converted to CO₂-equivalent (CO₂e). CO₂e "is a unit of measurement developed by the United Nations IPCC expert panel to standardize the climate impact of different greenhouse gases. [It] is also referred to as the Global Warming Potential (GWP)." ([Deutsche Gesellschaft für Nachhaltiges Bauen - DGNB e.V., 2021](#))

To be able to quantify climate costs at all, the greenhouse gas emissions must be determined over the entire life cycle of a building. The life cycle assessment standard for buildings DIN EN 15978 provides the methods and conventions for this.

In the German DGNB and BNB green building certification systems, life cycle assessment (LCA) has been mandatory for 15 years. Benchmarks for emissions such as CO₂e, with the reference unit m² net room area and year, have been established for evaluation. Since 2021, the *Bundesförderung effiziente Gebäude* (BEG *federal subsidy efficient buildings*) is bound to requirement values described in the BEG 40 NH class. The

Qualitätssiegel nachhaltiges Gebäude (QNG Quality Seal Sustainable Building) defines requirement values for primary energy demand and greenhouse gas emissions over the life cycle for new buildings receiving the subsidy. These are well suited as assessment benchmarks for climate protection targets but should be understood as minimum requirements. In the sense of Ballard's cardinal rule, within the TSD the requirement values according to QNG should also be firmly agreed as *allowable cost* by the project team and never be exceeded. To spur innovation the target emission should be set even below the QNG values. The approach of the Sustainable Target Value Design by Russell-Smith et al. (2015) starts at this point and shows a possibility to determine life cycle assessment values in short cycles during the planning process.

The CO₂ price per metric ton is €25 in 2021, according to the German government's decision. This value is to rise to between €55 and €65 per metric ton of CO₂ by 2026. That this is a purely politically determined value, becomes clear regarding the analyses by the German Federal Environment Agency (Umweltbundesamt - UBA): the agency drew up a methodological convention for determining environmental costs as early as 2007 and has continued to develop it. In 2020, new cost rates were published for greenhouse gas emissions.

Climate costs in Euro ₂₀₂₀ per ton of carbon dioxide	2020	2021	2030	2050
1% pure time preference rate (Higher weighting of the welfare of the current generation over the welfare of future generations)	199	201	219	255
0% pure time preference rate (Equal weighting of the welfare of the generations)	695	698	721	782
Source: Methodenkonvention 3.1 zur Ermittlung von Umweltkosten - Kostensätze und eigene Berechnungen (Umweltbundesamt, 2020)				

Figure 6
UBA recommendation on climate costs

[Figure 6](#) contains the UBA recommendations with and without consideration of a pure time preference rate (ZPR). This represents the weighting of the welfare of the generations. The level of the time preference rate in the valuation of environmental costs is debated worldwide and has been handled differently in different scientific papers so far ([Johannes, 2020](#)).

Using a pure time preference rate of 0%, present and future damages are equally weighted. If a pure time preference rate of 1% is used, only 74% of the damage incurred by the next generation (in 30 years) is taken into account, and only 55% of the damage incurred by the generation after next (in 60 years) ([Umweltbundesamt, 2020](#)).

The use of a positive time preference rate is based on the assumption of economic growth. It therefore assumes that the future generation will be economically better off than the present generation because of technological progress, which means that it will be better able to bear environmental consequential costs, for example.

However, this can lead to a paradox due to the rebound effect if economic growth (as in the past) is accompanied by more resource consumption and environmental pollution.

Accordingly, from the perspective of the German Federal Environmental Agency, the use of a time preference rate greater than 0 is ethically unjustifiable, as it contradicts the goal of intergenerational justice ([Umweltbundesamt, 2020](#)).

To achieve intergenerational justice - also with a view to the Paris climate protection agreement - ambitious climate protection goals such as CO₂ neutrality are required.

Which value is used in a project thus depends crucially on the attitude and ambition of the ordering parties. At this point, an interaction of the value of CO₂ pricing with intergenerational justice, which plays into the social aspects, is already emerging. This interaction is explained in more detail in the case study.

The overall aim should be to reverse the environmental impact. Instead of eco-efficient buildings that only minimize the negative effects, the aim should be to build eco-effective buildings that have a positive effect and are therefore useful for the environment.

6.6 Urban mine

Buildings that are useful for the environment are created when they function as stores of valuable materials after their use. As a rule, buildings lose value during their life cycle. At the end of the depreciation period, the building value is often negative when the structure is deconstructed. The urban mining design approach can give structures a positive building value because they are considered a raw material store.

The reason for the negative building value is that deconstruction generates waste that is costly to dispose of. Pollutants or inseparable mixed waste must be safely landfilled and cannot be fed into a recycling loop.

If investments are made initially in durable, reusable or recyclable materials and a flexible-use design, this may result in higher production costs, but the building will have a longer service life and the loss in value will be reduced. Additionally, commodity price trends are conducive to a positive building value. If materials that were previously brought in are sold during deconstruction, the price increase increases the structures value at the end of the lifecycle. The value development is shown in [Figure 7 \(Brenner, 2015\)](#).

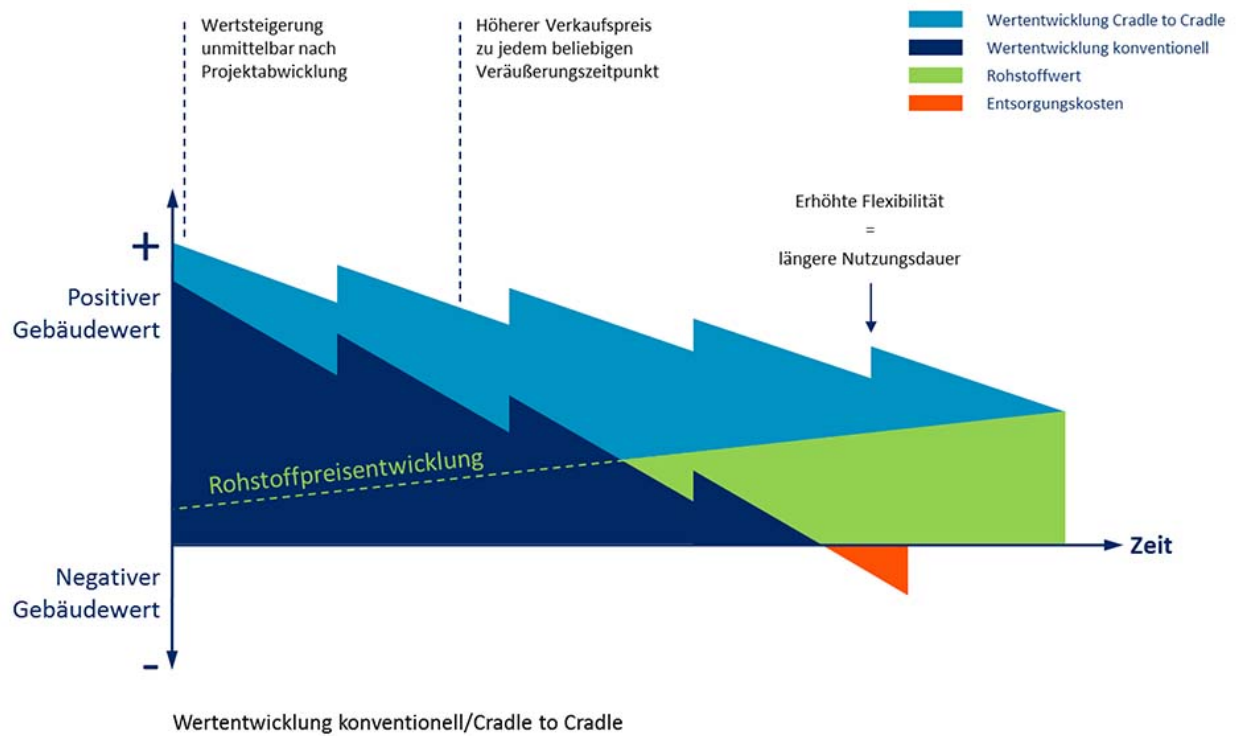


Figure 7
Value development conventional vs. cradle to cradle (Brenner, 2015)

Circular building turns structures into an urban mine. In circular building, the basic principle of consistent building is used, which means that buildings are built in a way that is compatible with natural cycles. The circularity of a building can be measured using various methods, such as the Urban Mining Index. This involves measuring how high the proportion of circular materials is. The value of the materials to be recovered plays a decisive role here (Rosen, 2021).



Figure 8

Systematics in the Urban Mining Index, LP= Loop Potential, CLP =Closed Loop Potential

6.7 TSD process Step 1

In the TSD, the sequence is the same as in the TVD. The difference, however, is that the factors are different and sustainability experts are also integrated into the Core Group. The TSD process of step 1 is shown in the flowchart in [Figure 9](#).

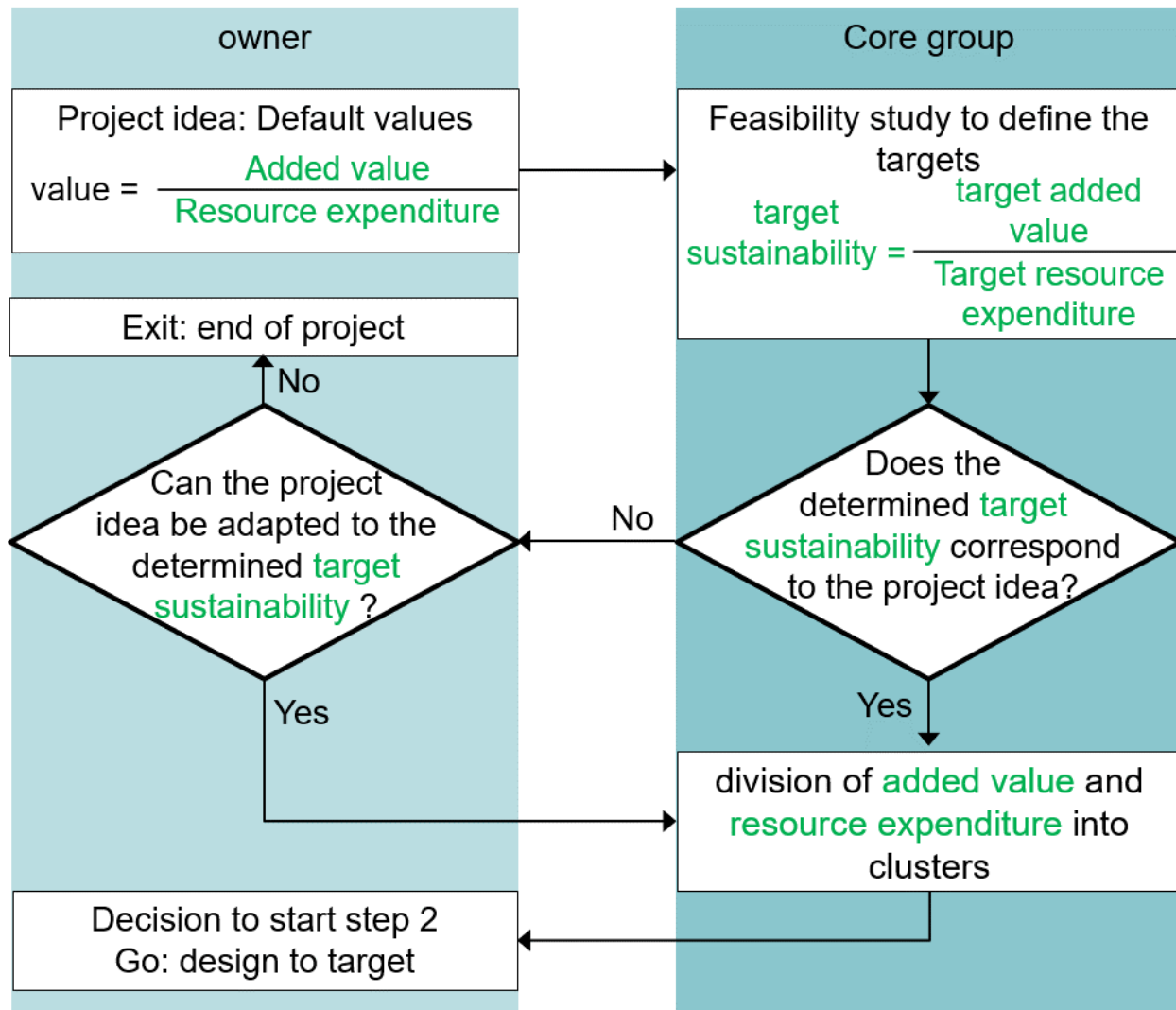


Figure 9
Flowchart TSD step 1 - set targets

The scope is replaced by the added value, which is described in more detail by the Core Group by means of the definition of formal objectives and material objectives. For this purpose, the objectives for each life cycle phase are recorded for each sustainability dimension. Accordingly, there will be environmental, social, and economic target formulations for the planning phase, the construction phase, the operating phase, and the recycling phase.

Analogously, the costs in the TSD are replaced by the resource expenditure. Accordingly, the expected life cycle costs, CO2 emissions and the value of the urban mine are determined in the feasibility study.

The result is presented to the ordering parties for decision and the further procedure is decided.

The detailed consideration of the project results in a comprehensive definition of objectives. Due to the large scope, it is necessary to familiarize all project participants with the goals so that silo thinking is prevented

within the clusters.

6.8 TSD process step 2

Analogous to the situation in step 1, the process in the TSD in step 2 - Design to Target does not change compared to the TVD. The change lays mainly in the composition of the cluster groups. In each cluster group there is also an expert for the assessment of sustainability factors, in particular life cycle costs, environmental impact costs and urban mine. The TSD process of step 2 is shown in the flowchart in [Figure 10](#).

During variant development, the results of the various factors in all variants must be presented transparently so that a robust decision can be made.

With the increase of factors to be considered, the complexity of the interactions between the factors within a cluster but also between the clusters increases. The requirements for the core group to evaluate the sum of the results of all clusters are increased accordingly, so that sustainability expertise must also be integrated into the core group.

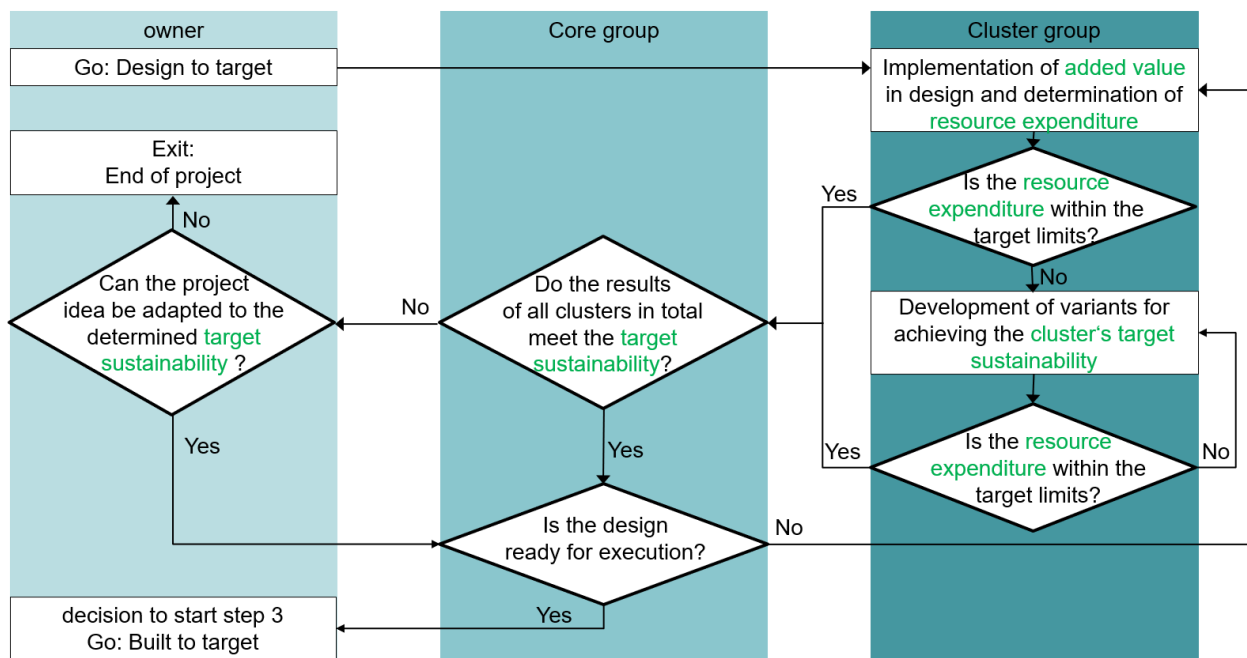


Figure 10
Flowchart TSD Step 2 - Design to Target (representation of a cycle)

7 Case Study

To verify the concept, a real case study was calculated as an example. The public project is a redevelopment of a university campus with a total GFA of 47'700 m². The conversion into an event center with a library will be carried out in several construction phases. In this process, 4 ground and base floors with 11'500 m² GFA each

will be newly connected. The room layout in the basement will be reconfigured accordingly. For this purpose, the existing sand-lime brickwork of the archive and storage rooms will be used for the construction of non-load-bearing sound and fire walls. This avoids the costs and CO₂ emissions associated with the production of new bricks. However, the non-destructive demolition of the masonry requires a lot of manual labor and high labor costs. Therefore, the removal and reinstallation of the bricks was tested in the first construction phase.

First, a deconstruction test was conducted on a 2.8 m wide by 2.9 m high wall to assess the feasibility of dismantling. The masonry was cut from top to bottom with an electric chisel and removed by hand. The remaining mortar was removed with a hand chisel. Broken bricks were sorted out. Approximately 90% of the stones were suitable for replacement. The raw density and compressive strength of the bricks were tested in the building materials laboratory to technically verify the reinstallation. Prior to reinstallation, the reused masonry was slurried so that damage to edges and corners is not a problem. Thus, the urban mining concept remains legible.

Based on the deconstruction test, it was possible to determine that for the required 111 m³ of masonry, about 130 m³ should be taken from the existing stock. To establish a comparison of costs and CO₂ emissions, the calculations are related to 1 m³ of masonry.

A comparison of the construction cost considers the following elements([Figure 11](#)):

Production cost	Deconstruction for reuse		Demolition, disposal & new production	
Share of reusable stones (without breakage)	90%		0%	
Deconstruction costs per m ² , wall thickness 11,5 cm	46	€/m ²	8	€/m ²
Disposal costs	1	€/m ²	6	€/m ²
Costs new material			21	€/m ²
Total cost per m ²	47	€/m ²	35	€/m ²
Cost per m ³ , rounded	410	€/m ³	300	€/m ³

Figure 11
Determination of production costs

Dismantling for reuse is thus uneconomical by current standards. However, reuse can avoid about 315 kg CO₂e/m³ caused by the production of new bricks. The climate costs are (as of 2021) [Figure 12](#):

Climate costs	1% pure time preference rate		0% pure time preference rate	
Price according to UBA	201	€/t.CO ₂ e	698	€/t.CO ₂ e
minus emissions paid from the EU Emissions Trading (EU-ETS) (Umweltbundesamt, 2022)	-52		-52	
Uncovered consequential climate costs	148		645	
related to 1m ³ newly produced sand-lime brickwork	47 €/m ³		204 €/m ³	

Figure 12
Determination of climate costs

The cost comparison for the KS masonry including the climatic costs is as follows (Figure 13):

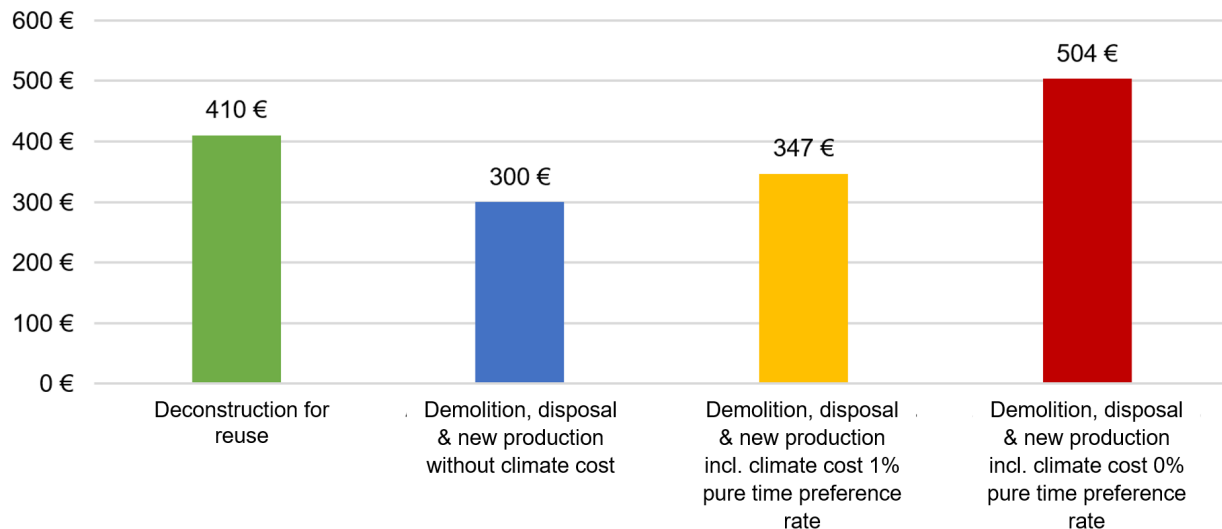


Figure 13
Comparison of the costs of reused and new masonry without and with climate costs, CO₂ prices according to UBA (prices in €/m³)

Figure 11: Exemplary comparison of the costs of reused and new masonry without and with climate costs, CO₂ prices according to UBA (prices in €/m³)³

The comparison makes it clear that the sustainable reuse of used building materials in the example described becomes economical when intergenerational equity is taken into account and the environmental impact costs are calculated with 0% time preference.

This example is shown below in the TSD formula. Here, the life cycle costs in the variants correspond to the production costs (since no utilization costs arise). The environmental impact costs are (simplified) represented

by the climate costs. In the example project, it was determined based on a deconstruction test that the deconstruction process enables a later reuse of 90% of the existing building fabric. Accordingly, 90% of the value of the new material can be applied to the urban mine ($21\text{€}/\text{m}^2 / 0.115 \text{ m} * 0.9 = 164 \text{ €}/\text{m}^3$). It is questionable how many bricks can be usefully deconstructed for a third use cycle. Based on the 90% determined in the test, $90*90 = 81\%$ is assumed for this cycle ($21\text{€}/\text{m}^2 / 0.115 \text{ m} * 0.81 = 148 \text{ €}/\text{m}^3$). Accordingly, the value of the urban mine is reduced for variant 1 reuse. This example shows that KS walls are not predestined for reuse because they are mortared.

Assuming that with the structural solution the functional, qualitative and social requirements are fully met (100%) and there are no differences between the variants here, the variants can be presented as follows:

Variant 1 Reuse:

$$\frac{\text{Life cycle costs} + \text{environmental impact costs} - \text{Urban mine}}{100\%} = 0,38$$

$$\frac{410 \text{ €}/\text{m}^3 + 0 \text{ €}/\text{m}^3 - 148 \text{ €}/\text{m}^3}{100\%} = 0,38$$

Figure 14
Variant 1 Reuse

Since variant 2 does not consider environmental impact costs and thus does not take all factors into account, this variant cannot be used for a comparison in the TSD.

Variant 3 no reuse, climate costs with 1% ZPR:

$$\frac{\text{Life cycle costs} + \text{environmental impact costs} - \text{Urban mine}}{100\%} = 0,55$$

$$\frac{300 \text{ €}/\text{m}^3 + 47 \text{ €}/\text{m}^3 - 164 \text{ €}/\text{m}^3}{100\%} = 0,55$$

Figure 15
Variant 3 no reuse, climate costs with 1% ZPR

Variant 4 no reuse, climate costs with 0% ZPR:

$$\frac{\text{Life cycle costs} + \text{environmental impact costs} - \text{Urban mine}}{100\%} = 0,29$$

$$\frac{300 \text{ €}/\text{m}^3 + 204 \text{ €}/\text{m}^3 - 164 \text{ €}/\text{m}^3}{100\%} = 0,29$$

Figure 16
Variant 4 no reuse, climate costs with 0% ZPR

If we look at the example, we see that variant 3 achieves the highest value. The reason for this is the 1% discounting of the environmental impact costs. To understand the meaning of discounting, it is important to look at it from a societal rather than a business perspective. The valuation of the discount rate of 1% means that it is assumed that future generations will have a greater material endowment at their disposal, which will enable them to bear the environmental burdens better than the present generation. Accordingly, the environmental consequential costs are lower. The basis of this assumption is economic growth or efficiency growth as a result of technological progress ([Umweltbundesamt, 2018](#)). As already described, economic growth has so far been accompanied by increased resource consumption, so that the social effect assumed with discounting is unlikely to materialize.

In variant 3, this results in unequal treatment between the future company and the current company. Variants 1 and 4 are not based on such unequal treatment. Accordingly, the comparison of variants 1, 3 and 4 is inconsistent if all dimensions of sustainability are to be considered.

As compensation, the equal treatment of the future society compared to the present one, if not reflected in the environmental impact costs, can be included in the social factors. For this purpose, the scope in the numerator is reduced by the social benefit, consisting of the difference between today's and the future effort.

The basic idea here is that the longer a building is used, the longer it serves society and the greater the generational equity and the social benefit.

Three numerical examples are provided for illustrative purposes:

Discounting at 1%, it is assumed that in 30 years only $(100\%-1\%)^{30} = 74\%$ of today's effort will be required. Accordingly, the social benefit is 26%.

With a useful life of 50 years, $(100\%-1\%)^{50} = 61\%$ of the expenses are incurred. The social benefit increases accordingly to 39%.

A useful life of 200 years, which is not unusual for monuments, requires $(100\%-1\%)^{200} = 13\%$ and allows a social benefit of 87%.

These examples show that the length of the life cycle of a building is an important factor in determining the social benefit. In order to determine the length of a life cycle, reference can be made to the Guidelines for Sustainable Construction of the German Federal Ministry of the Interior, for Construction and for the Homeland. Here, the system boundary and thus the period for a life cycle consisting of planning, construction, use and deconstruction is defined for sustainability assessments. For example, the observation period of a life cycle for an office and administration building is defined as 50 years ([Bundesministerium des Innern, für Bau und Heimat 2019, 25](#)).

If we now apply this scale to our variant 3, we can set up variant 3a as follows.

Variant 3a no reuse, climate costs with 1% ZPR, life cycle 50 years:

$$\frac{100\% * 39\% \text{ (social benefit)}}{\text{Life cycle costs} + \text{environmental impact costs} - \text{Urban mine}} = 0,21$$

$$\frac{\quad}{300 \text{ €/m}^3 + 47 \text{ €/m}^3 - 164 \text{ €/m}^3}$$

Figure 17

Variant 3a no reuse, climate costs with 1% ZPR, life cycle 50 years.

If we now compare variant 1, 3a and 4, we see that the value of variant 1 is the highest.

This example shows how, in addition to the environmental costs, social factors and in particular intergenerational equity can affect the value of a variant and thus the assessment of variants.

8 Findings and Conclusion

With the development of Target Sustainability Design, it is argued that by monetizing environmental targets, they can form a common lever with economic targets for the value of a structure. However, this common leverage can only occur when both monetary and natural resources are considered as a total resource. This holistic view allows for the common placement of resource expenditures in the denominator of the equation, in juxtaposition with the qualitative, functional, and social values in the numerator.

A key finding of the case study is that the CO₂ price used has a significant impact on the sustainable value outcome. Only when using a CO₂ price with a time preference rate of 0 are the costs allocated where they are caused. When choosing a CO₂ price with a time preference rate greater than 0, the environmental costs of construction projects are passed on to future generations. This means that values are generated today that society will have to pay for in the future. The observation period is therefore of essential importance for the choice of a reasonable CO₂ price. For public clients who act with the financial resources of society, a time preference rate greater than 0 is equivalent to shifting costs into the future. Private investors as members of society are currently only affected indirectly by the environmental costs. Regardless of who actually bears the costs, a generation-fair CO₂ price also gives private investors a transparent and reliable basis for sustainable decision-making.

With the case study, the effects of intergenerational equity could be presented within the carbon price or as part of the social benefit. It became apparent that the sustainable value of a building is determined not only by the functional and qualitative requirements but also by the needs of today's and tomorrow's society. This was shown in the case study by the fact that the useful life could have a significant impact on the sustainable value. The inclusion of the useful life corrected the initially higher valued variant in such a way that it ended up being

the lowest valued variant. It would be interesting to find out in another case study how the durability of different construction methods could affect the sustainable value via the social benefit.

With its basic approach, the urban mining approach moves in the environmental dimension of buildings. With the value assessment at the end of a life cycle, the economic dimension is integrated into the approach with the monetary valuation of the remaining materials. For example, the case study found that a structure not designed for reuse loses monetary value when it is reused and thus has a depressing effect on sustainable value. The influence of reusability and recyclability on the sustainable value should be determined in further case studies. Here, the comparison of variants with different types of construction and materials is of particular interest, as the resilience of the TSD could be further increased on this basis.

The case study also shows the interactions between LCC and LCA. Complex dismantling work, for example, is reflected directly in the LCC as high labor costs, while at the same time the environmental impact costs are reduced due to avoided emissions. From this, it can be concluded that constructions that are already planned and executed with the idea of later reuse, in addition to reduced environmental follow-up costs, also show reduced life cycle costs and thus result in an increased sustainable value. This approach should be verified by investigating variants with different deconstruction efforts.

To complete the TSD, the monetization of other LCA factors such as water consumption, acidification potential, ozone depletion potential, etc. should be further promoted. This allows these factors to be included in the equation in the same way as carbon costs, creating a more comprehensive basis for decision-making. For the LCC and LCA investigations to be effectively included in the TSD, however, the effort involved in the investigations must be kept to a minimum. Accordingly, when supplementing the values, the process of data determination must also be considered, which affects not only environmental factors but also social factors.

Based on the many connecting points, it becomes apparent that the consideration of interactions of environmental, economic, and social aspects yields multi-layered results. The simplification to a formula with one result value can support the decision between different variants. Overall, it can therefore be stated that the perspective broadened with the TSD to include the entire life cycle of a structure with its environmental and social effectiveness and the consideration of the urban mine provides a comprehensive basis for sustainable decisions.

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