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BIM-BASED ASSESSMENT OF ECOLOGICAL, ECONOMIC AND SOCIAL SUSTAINABILITY FOR PLANNING WITHOUT SUSTAINABILITY EXPERTISE

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Abstract

The challenges of climate change and resource scarcity are significant for the construction sector. In particular, materials such as concrete and masonry produce high CO_2 emissions and require large amounts of limited raw materials. There are currently no practical tools for assessing building materials against a wide range of sustainability criteria in accordance with the client's requirements in the early stages of planning. Furthermore, it is difficult to check whether the requirements of the criteria have been satisfied during this process without specialist knowledge.

This study develops a prototype using the graphical programming interface Dynamo to create an automated system for assessing the sustainability of building materials. Ecological, economic and social data from existing databases are linked with quantities from digital building models in the authoring software Revit. The system scores materials based on defined criteria and weights. It then provides an automated result to quantify the sustainability of the building, without requiring the expertise of the designer. The results of the sustainability assessment are ultimately added to and stored within the project's building information.

The prototype was validated using the masonry walls in the building model. The results show that the prototype enables a standardized and simple sustainability assessment of building materials. For example, it can evaluate not only the amount of CO_2 equivalents, but also the associated life cycle costs, and the material-related transmission factor can be automatically determined and evaluated.

A limitation of the paper is that energy efficiency is only considered for building materials, while other construction systems such as installations are not included. Therefore, the overall assessment is limited to the materials without considering the interactions with other systems. Furthermore, the connection to external data sources is static, so automatic data updates are not possible. A dynamic integration of new data would improve the adaptability and timeliness of the approach.

Keywords: Automation, BIM, Lifecycle, Materials, Sustainability.

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1. Introduction

1.1. Motivation

Given the global commitment to climate and resource protection, the construction sector has a key role to play in achieving international climate targets and in the transition to a resource-efficient economy. With a share of around 40% of national greenhouse gas emissions, around 70% of the consumption of non-renewable raw materials and 55% of waste generation, the construction industry is one of the biggest producers of environmental pollution [1]. Emissions are generated both in the operation of buildings, for example through energy consumption for heating, cooling and electricity, as well as through the energy-intensive production of building materials such as cement, steel and bricks [2]. As a result, sustainable construction methods play a key role in achieving national and international climate targets. As part of the Paris Agreement signed in 2015, 195 countries - including Germany and the European Union - have made a commitment under international law to limit the increase in the global average temperature to 1.5 °C and well below 2 °C compared to pre-industrial levels [3]. To realize these goals, the European 'Fit for 55' package provides for a reduction in greenhouse gas emissions of at least 55% by 2030 and climate neutrality in Europe by 2050 [4].

A key lever for achieving these goals is the early assessment and optimization of the sustainability of buildings - ideally as early as the planning phase. However, in the early project phases, where the influence on the subsequent sustainability performance of a building is highest, the necessary tools, data and assessment methods to make informed decisions are often lacking [5]. The integration of ecological, economic and social sustainability aspects requires specialized expertise as well as access to detailed and structured information [6]. In practice, this structural gap between planners' scope for action and available methodological support often prevents consistent sustainable building planning. In order to meet this need, intuitive and easily accessible approaches are required that enable sustainability assessment in the early planning phases - even without in-depth specialist knowledge. Building Information Modelling (BIM) makes it possible to treat a building as a comprehensive data model. This model integrates architectural details, structural components and technical systems. The available data can be used to carry out analyses and evaluations and identify optimization potential at an early stage. [7]

1.2. Purpose & structure

The objective of this paper is to develop a prototype for the automated assessment of the sustainability of a building's construction based on selected ecological, economic and social indicators during the early planning phase. The approach of the paper aims to enable a BIM-based sustainability assessment that does not require specific expertise from planners. The focus is particularly on non-experts in the field of sustainability, as sustainability assessments are complex in terms of calculation, data collection and analysis. To achieve this goal, a prototype is implemented with the proprietary solution in Dynamo-Revit to achieve fast and quantifiable results during the planning phase. Since the requirements for the evaluation of building structures such as ceilings or walls vary depending on the type of construction, this paper initially focuses on masonry walls of a building. This example is used to develop an approach that can later be extended to other building structures. The implementation of such a system comprises three main steps:

1. **Input determination:** Identification of the sustainability assessment indicators and automated processing of the values from the digital building model.
2. **Processing of input parameters:** Application of the calculation rules for the sustainability assessment.
3. **Output of the sustainability assessment:** Presentation of the result for further planning and optimization.

To define the inputs, relevant sustainability criteria for masonry walls from an economic, ecological and social perspective are first identified by means of literature research and indicators are defined for quantification. The data required for the indicators are either added to the model for all component groups in the model or obtained from external databases.

To process the input parameters, an approach is developed that has functions for importing sustainability data into Dynamo-Revit and linking it to the building model. The results are then analyzed in a way that is clear and accessible to non-experts, so that a sustainability assessment can be carried out. The practical suitability of the model is checked by validating it on a realistic 3D model. Finally, the implementation of the sustainability assessment is analyzed and discussed with statements on the use case.

The main research question of this paper is therefore:

- How can a BIM-based prototype be developed that enables an automatic assessment of the sustainability of building structures during the planning phase by integrating selected ecological, economic and social indicators without the specific expertise of the planners?

This research question leads to further, subordinate research questions:

- Which specific indicators are relevant for assessing the environmental, economic and social sustainability of masonry buildings and how can these indicators be evaluated? (Chapter 3)
- How can sustainability data be integrated into digital building models? (Chapter 4)
- How can the results of the analysis of digital building models be interpreted and visualized to ensure their practical applicability and user-friendliness? (Chapter 5)

2. Related Works

For the sustainability assessment of buildings, various systems are used, such as BREEAM, LEED and DGNB [8–10]. On the one hand, the assessment schemes consider sustainability in terms of the three pillars: ecological, economic and social [11]. On the other hand, other domains, such as technology or processes, can also be included in the sustainability assessment [12, 13].

Due to the increasing establishment of the BIM method, the associated digital 3D building models with semantic data increasingly serve as a database for carrying out sustainability assessments of buildings. Along the life cycle of buildings, there are many articles on the topic of sustainability assessment of buildings. A selection of articles with different specificities is presented below:

Sustainability assessments based on 3D models using BIM follow a holistic approach and comprise the entire buldings life cycle. In their article, Carvalho et al. present a BIM-based approach for a life cycle-orientated sustainability assessment of buildings in Portugal. The focus here is on the linking and different weighting of individual life cycle phases as well as the interoperable interface with databases.[14] Furthermore, Azhar and Brown compare various software applications for sustainability assessment, considering all life cycle phases. The results of the software comparison are used to develop a framework for a standardized sustainability assessment process based on digital 3D building models.[15] Another article on the life cycle for sustainability assessment of buildings, published by Mohammed, explores basic sustainability indicators along the life cycle and the creation of interoperability with BIM platforms. At the same time, the article explores further strategies for linking digital BIM models, BIM platforms and sustainability assessment systems.[16] In contrast, Santos et al. develop their own tool for BIM-based sustainability assessment instead of using existing software applications. In this context, the focus is on the link to BIM libraries and models with different data depths in the ecological and environmental sustainability pillar.[17] While the previously presented articles address buildings in normal on-site construction, Ji et al. focus on the ecological assessment of buildings in prefabricated construction.[18]

In addition to the focus on the entire life cycle of the sustainability assessment, there are also BIM-based approaches that only consider individual phases, such as the planning or operation of a building. Several approaches for the sustainability assessment of buildings in the planning phase are for example proposed by Kamari et al., Zanni et al. or Lim [19–22]. Moreover, additional approaches are developed for the operation of buildings in connection with energy consumption, e.g. in Tushar et al., Ghanbari et al. [23, 24]

In general, the research area of BIM-based sustainability assessment of buildings is highly relevant and significant for the future of the construction industry [25]. The articles presented above are only exemplary excerpts about different life cycle orientated or phase-specific approaches for a sustainability assessment of buildings using the BIM method. This article draws on the principles of BIM-based sustainability assessment but looks specifically at the design of masonry buildings. In addition to defining suitable sustainability parameters for all three pillars - ecological, environmental and social - the focus is also on creating partial automation and interoperability of the workflow.

3. Sustainability framework and calculation

Sustainability is defined and described in different ways in the scientific literature. Essentially, it combines ecological, economic and social dimensions that are interdependent. The following approaches, for example, are defined in the literature.

Ecological sustainability aims to conserve resources in construction and considers environmental impacts such as CO_2 emissions using methods such as life cycle assessment in accordance with DIN EN ISO 14040 [26, 27]. Economic sustainability focusses on the life cycle costs of buildings such as life cycle cost data [26, 28]. Social sustainability emphasizes user comfort and health, with criteria such as accessibility and acoustic comfort [28, 29].

Sustainability is defined and described differently depending on the source. In order to avoid having to redefine the concept of sustainability, this paper uses the BNB (Bewertungssystem nachhaltiges Bauen) existing sustainability rating system for the sustainability indicators. The BNB is a tool for planning and assessing sustainable, typically public construction projects. It complements the Federal Ministry's Sustainable Building Guide as a holistic evaluation methodology for buildings and their surroundings. For a holistic view it is necessary to integrate all criteria of this system. To simplify this, the focus in this paper is initially on the building's construction and specifically on the walls. This means that only the factors that influence the wall are analysed and listed. The following sections explain which of the BNB's environmental, economic and social sustainability indicators are taken into account and how they are assessed. [30]

Ecological sustainability (BNB)

Suitable indicators are needed to quantify and evaluate sustainability. The following ecological factors identified for this work are taken from the BNB assessment system, which already has quantifiable indicators. As the focus here is on masonry, a selection of indicators was made that can be applied to masonry. These are the global warming potential (GWP), the primary energy demand (PE) in variations and the ozone depletion potential (ODP). This selection was also made as the corresponding values can be taken from the environmental product declarations (EPD) or ÖKOBAUDAT in order to simplify the automation process.

Quantification of ecological sustainability indicators									
Indicator					Assessment				Data source
#	Name	Source	Description	Unit	Limit values	Score	Formula	Source	
1.1	GWP	BNB BN 2015 1.1.1	Global Warming Potential, total	kg CO_{2e}/m^2_{NRF} * a	1. <= 24 2. = 37 3. >= 66	6 3 0 (Interpolated)	GWP = $\sum$GWP-total$_{Ökobaudat}$ / m^2_{NRA}*a -oder- $\sum$GWP$_{Ökobaudat}$ / m^2_{NRA}*a	BNB BN 2015 1.1.1	ÖKOBAUDAT
1.2	PE_{AN}	BNB BN 2015 1.2.1	Primary energy demand level of requirement	N/A	1. >= 100 2. = 50 3. <= 10	6 3 0 (Interpolated)	PE_{AN} = $\sum_{Score}$(PENRT, PERT%, PE_{ges})	BNB BN 2015 1.2.1	N/A
1.2.1	PENRT	BNB BN 2015 1.2.1	Primary energy demand non-renewable, total	kWh/m^2_{NRF} * a	1. <= 109 2. = 167 3. >= 277	60 30 6 (Interpolated)	PENRT = ($\sum$PENRT$_{Ökobaudat}$) / m^2_{NRF}*a	BNB BN 2015 1.2.1	ÖKOBAUDAT
1.2.2	PE_{ges}	BNB BN 2015 1.2.1	Primary energy demand, total	kWh/m^2_{NRF} * a	1. <= 121 2. = 204 3. >= 343	40 20 4 (Interpolated)	PE_{ges} = PENRT + PERT PERT = ($\sum$PERT$_{Ökobaudat}$) / m^2_{NRF}*a	BNB BN 2015 1.2.1	N/A
1.2.3	PERT%	BNB BN 2015 1.2.1	Primary energy requirement renewable	% (from PE_{ges})	1. >= 37 2. = 29 3. = 15 4. < 15	20 10 2 0 (Interpolated)	PERT% = (PERT/PE_{ges})*100 PERT = ($\sum$PERT$_{Ökobaudat}$) / m^2_{NRF}*a	BNB BN 2015 1.2.1	ÖKOBAUDAT
1.3	ODP	BNB BN 2015 1.1.2	Ozone depletion potential	kg R_{11}/m^2_{NRF} * a	1. <= 1,101*E-7 2. = 1,390*E-7 3. >= 2,480*E-7	6 3 0 (Interpolated)	ODP = ($\sum$ODP$_{Ökobaudat}$) / m^2_{NRF}*a	BNB BN 2015 1.1.2	ÖKOBAUDAT

Figure 1: Calculation method of the environmental sustainability indicators

Economic sustainability (BNB)

In order to assess economic sustainability, the BNB methodology was employed, which is based on a life cycle cost analysis. Despite the fact that all indicators were incorporated, the calculation was adapted for masonry. The assessment comprises a single indicator, namely the life cycle costs per m^2 (LCC/LZK), which is further divided into multiple sub-indicators. For instance, the production costs of encompassing masonry (KH01) and the present value of the utilization costs of masonry (C_0) are pertinent to the assessment. C_0 is derived from the utilization costs for maintenance and construction (KN01 and KN02).

Quantification of economic sustainability indicators									
Indicator					Assessment				Data source
#	Name	Source	Description	Unit	Limit values	Score	Formula	Source	
2.1	LZK	BNB BN 2015 2.1.1	Life cycle cost per m^2	EUR/m^2_{NRF}	1. <= 3.300 2. = 4.800 3. >= 6.400	6 3 0 (Interpolated)	LZK = $(KH01 + C_0)/m^2_{NRF}$	BNB BN 2015 2.1.1	Manufacturer / supplier / service provider etc.
2.1.1	KH01	BNB BN 2015 2.1.1 DIN 276	Production costs KG300 Building - building structures	EUR	N/A	N/A	KH01 = $(K_{material} + K_{labor})/f$ f - location factor	BNB BN 2015 2.1.1	Manufacturer / supplier / service provider etc.
2.1.2	C_0	BNB BN 2015 2.1.1	Present value of utilization costs	EUR	N/A	N/A	$C_0 = \sum C_j$ (here: KN01+KN02) C_j(KN01, KN02) = $\sum (K_{t,j} * (1+ m_j)^t) / (1+i)^t$ C_j - Partial cash value; $K_{t,j}$ - Costs in period t; t - 0<=Year<=50; i - Interest rate; m - Price increase according to Appendix 4	BNB BN 2015 2.1.1	Manufacturer / supplier / service provider etc.
2.1.2.1	KN01	BNB BN 2015 2.1.1 DIN 276 DIN 18960	Utilization costs NKG 300 Maintenance & inspection, Annual	EUR/a	N/A	N/A	KN01 = 0,1 % * KH01	BNB BN 2015 2.1.1	KH01
2.1.2.2	KN02	BNB BN 2015 2.1.1 DIN 276 DIN 18960	Utilization costs NKG 410 Maintenance of construction, Annual	EUR/a	N/A	N/A	KN02 = 0,35 % * KH01	BNB BN 2015 2.1.1	KH01

Figure 2: Calculation method of the economic sustainability indicators

Social sustainability (BNB)

Despite the challenges encountered in the search for quantifiable social indicators related to masonry, the BNB provided valuable information that facilitated this investigation. The concept of social sustainability in the context of masonry can be defined as the enhancement of comfort, cosiness and safety for users or residents through the consideration of specific features. The parameters under consideration are as follows: airborne sound insulation (R'_w), thermal resistance (R) and fire resistance class (FWK). Due to the high complexity of R'_w, it is necessary to make assumptions about it. Without these assumptions, complex geometric analyses need to be carried out. The BNB does not mention the fire resistance class, but it is included as an additional criterion in the assessment of masonry.

Quantification of socio-cultural sustainability indicators									
Indicator					Assessment				Data source
#	Name	Source	Description	Unit	Limit values	Score	Formula	Source	
3.1	R'_w	Based on BNB BN 2015 4.1.1 DIN 4109	Soundproofing, Airborne sound insulation	dB	1. >= 64 dB 2. = 59 dB 3. < 59 dB	6 3 0 (Interpolated)	$R_w = 30{,}9 \lg(m'_{ges}/m'_0) - 22{,}2$ (dB) m'_{ges} - surface-related mass of the component 65 kg/m² < m'_{ges} < 720 kg/m²; m'_0 - Reference value (= 1kg/m²)	BNB BN 2015 4.1.1 DIN 4109-1:2018-01 Table 3 (Walls on bottom floor) DIN 4109-32:2016-07, Formula 13	ÖKOBAUDAT / EPD / Hersteller etc.
3.2.1	$R_{100+,a}$	Based on BNB BN 2015 4.1.2 DIN 4108-2	Thermal resistance Mass >= 100kg/m² Exterior wall	m²K/W	1. >= 10,31* 2. >= 1,2 3. < 1,2	6 3 0 (Interpolated)	$R_{100+,a} = (R_{si}+(d_1/\lambda_1+\ldots+d_n/\lambda_n)+R_{se})$ according to DIN EN ISO 6949	DIN 4108-2:2013-02 Table 3, Line 1	ÖKOBAUDAT / EPD / Manufacturer etc.
3.2.2	$R_{100+,i}$	Based on BNB BN 2015 4.1.2 DIN 4108-2	Thermal resistance Mass >= 100kg/m² Interior Wall	m²K/W	1. >= 10,31* 2. >= 0,07 3. < 0,07	6 3 0 (Interpolated)	$R_{100+,i} = (R_{si}+(d_1/\lambda_1+\ldots+d_n/\lambda_n)+R_{se})$ according to DIN EN ISO 6949	DIN 4108-2:2013-02 Table 3, Line 6.1	ÖKOBAUDAT / EPD / Manufacturer etc.
3.3	R_{99}	Based on BNB BN 2015 4.1.2 DIN 4108-2	Thermal resistance Mass < 100kg/m²	m²K/W	1. >= 10,31* 2. >= 1,75 3. < 1,75	6 3 0 (Interpolated)	N/A	DIN 4108-2:2013-02 Section 5.1.2.2	ÖKOBAUDAT / EPD / Manufacturer etc.
3.4	FWK	DIN EN 13501-1	Fire resistance class Building material class	N/A	1. A1 2. A2 3. B 4. C 5. D 6. E 7. F	6 5 4 3 2 1 0	N/A	own rating system	EPD / Manufacturer etc.

* *Note:* Limit value corresponds to uninsulated brick (365 mm) + vacuum insulation (50 mm)

Figure 3: Calculation method of the social sustainability indicators

In the next step of the evaluation, the sustainability dimensions are weighted based on the identified indicators. A differentiation is made between two approaches. Either a specific weighting is entered based on the requirements, e.g. of the client, or the dimensions are considered equal if no specific weighting is specified.

1. **User-defined weighting:** Individual weightings (0-100%) for the three dimensions lead to a project-specific degree of fulfilment, e.g. 50% for ecology, 36% for economy and 14% for social aspects.
2. **Unweighted calculation**: Each dimension (ecology, economy, social aspects) is taken into account equally (33.33%). Points for indicators such as R'w are included according to their share of the total mass. The degree of fulfillment results from the ratio of points achieved to the maximum possible points.

The overall result shows the remaining sustainability potential of the project by subtracting it from 100%. The level of the project is assessed on the basis of the overall degree of fulfilment in five levels, each of which is divided into 20% increments: Very Good, Good, Neutral, Poor and Very Poor. This rating is designed to help users understand how sustainable their project is and how it performs under user-defined requirements.

Figure 4 summarizes all the steps for calculating the sustainability assessment. From left to right, these include the evaluation of the indicators, the calculation of the degree of fulfillment, the weighting of the degree of fulfillment and finally the consolidation with the evaluation.

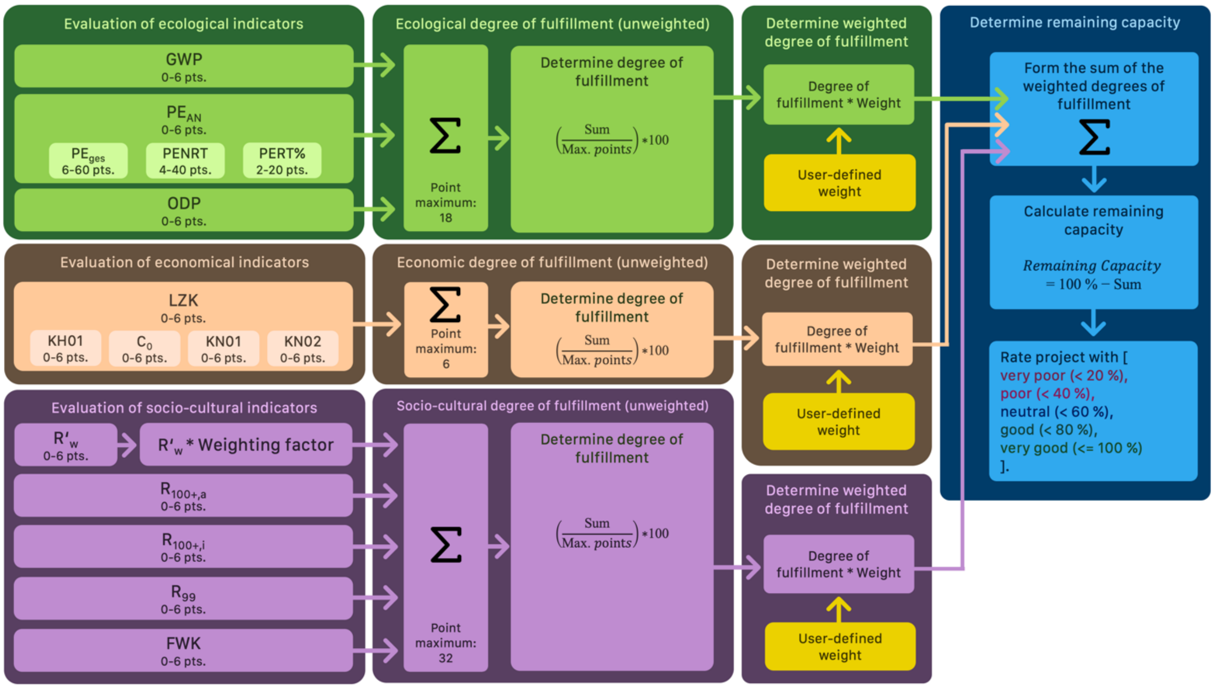

Figure 4: Sustainability framework and calculation for the prototype

4. Data sources

The aim is to store all relevant data in the model as a single source of truth (SSOT) in order to create a centralized and consistent source of information. The 'LCA plugin for BIM software' workflow, in which sustainability assessments are carried out in the authoring software itself, is used according to Wastiel & Decuypere [31]. Ecological data, which is available in the form of EPD datasets, is extracted directly from the database and then linked to the digital model. The ÖKOBAUDAT database platform created by the Federal Ministry of Housing, Urban Development and Building of Germany is used here, which provides all stakeholders with a standardized database for the life cycle assessment of buildings.

In order to successfully extract information from the model and carry out an automated sustainability assessment, the materials must have certain properties in the authoring software. In addition to the material name in the model, the properties must contain additional parameters such as fire resistance class, cost per cubic meter, thermal conductivity and density in accordance with the requirements of the sustainability assessment. Furthermore, it is important that the material name exactly matches the name in ÖKOBAUDAT to ensure a link. To facilitate the search for project materials, each material is labelled with a keyword such as ÖKOBAUDAT. This enables quick identification and selection of ÖKOBAUDAT materials for the standardization of material families.

5. Prototype

5.1. Prototyping

Based on the previous chapters, a prototype is developed that enables planners to carry out sustainability assessments without extensive specialized knowledge in sustainability assessments. The prototype focusses on providing a practical and simple way for the assessment. It is created using a plugin approach via Dynamo Revit. This integrates various software components and data sources. The information flow starts with the import of relevant data into the software environment. The system then evaluates various dimensions of sustainability: ecological, economic and social. The results are presented in both unweighted and weighted form via a user interface. Finally, these results are written back into the building model so that they can be saved and exported. The four main areas for creating the sustainability assessment are shown below (Figure 5) and then explained step by step.

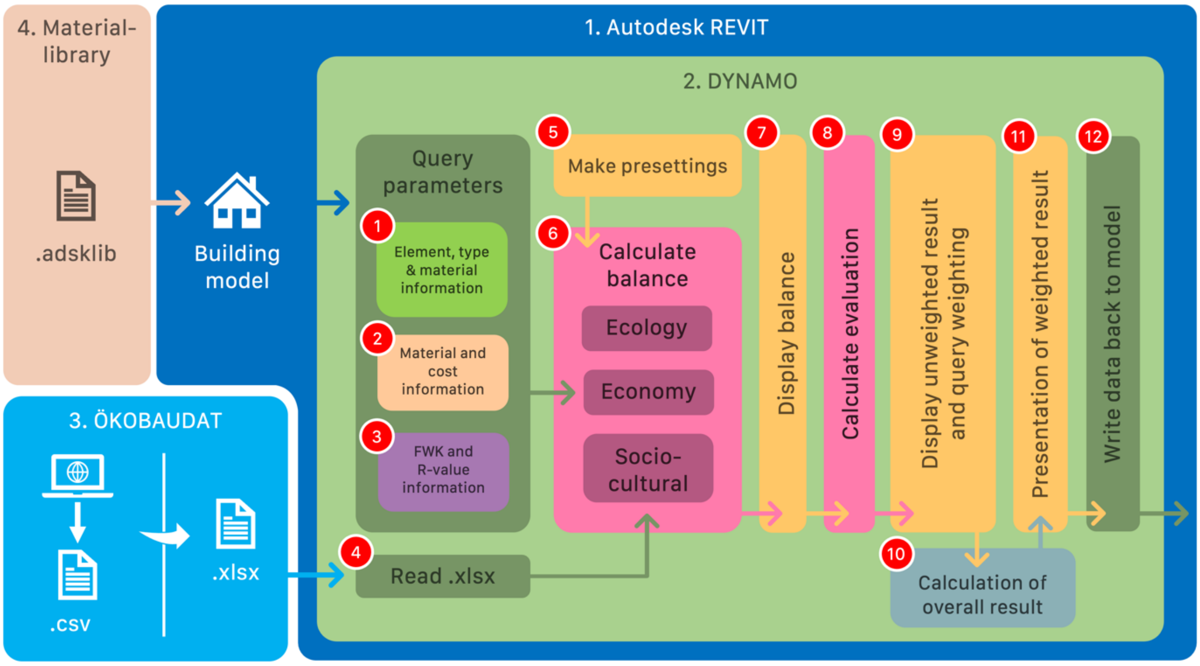

Figure 5: Steps towards sustainability assessment

- **Basic parameter queries:** Captures information such as area, volume, thermal resistance and material name for each component of type "wall", which is stored in a list.
- **Economic information:** Query type name and cost per cubic meter, linked to the Universally Unique Identifier (UUID) for unique assignment.
- **Social information:** Captures the fire resistance class and function of the wall (internal/external). A Python block calculates the degree of fulfillment of the fire resistance class based on the project volume and scores.
- **Ecological information:** Imports data from the .xlsx file of ÖKOBAUDAT, which is prepared as a list.
- **Assessment calculation:** Creates assessment sheets for the three sustainability dimensions; ecological indicators are filtered, economic indicators calculate manufacturing and utilization costs, social indicators evaluate fire resistance class and thermal resistance.
- **Output of the assessments:** Presents assessment data in tabular form using the calculation methods from Chapter 3
- **Evaluation of the dimensions**: Calculates unweighted results of each dimension using previous assessment data.
- **Weighting by users:** If required, users can define individual weightings for each dimension using sliders.
- **Final user output:** Shows the overall result with weighted results including a statement on the sustainability of the building ("very poor" to "very good") and the optimization potential as a percentage.
- **Write back to the building model:** Save compliance levels and weights as new parameters in Revit for export or viewing for other users.

5.2. Testing

To validate the prototype, a building model with the requirements from chapter 3 is created in Revit. Wall families with the described material properties are configured here. The building represents an average house with a foundation, two stories, a suspended ceiling as well as doors, windows and a roof. The following figure shows the model and, in the background, the parameterized walls with their specific properties, which are only shown to illustrate the wall types used.

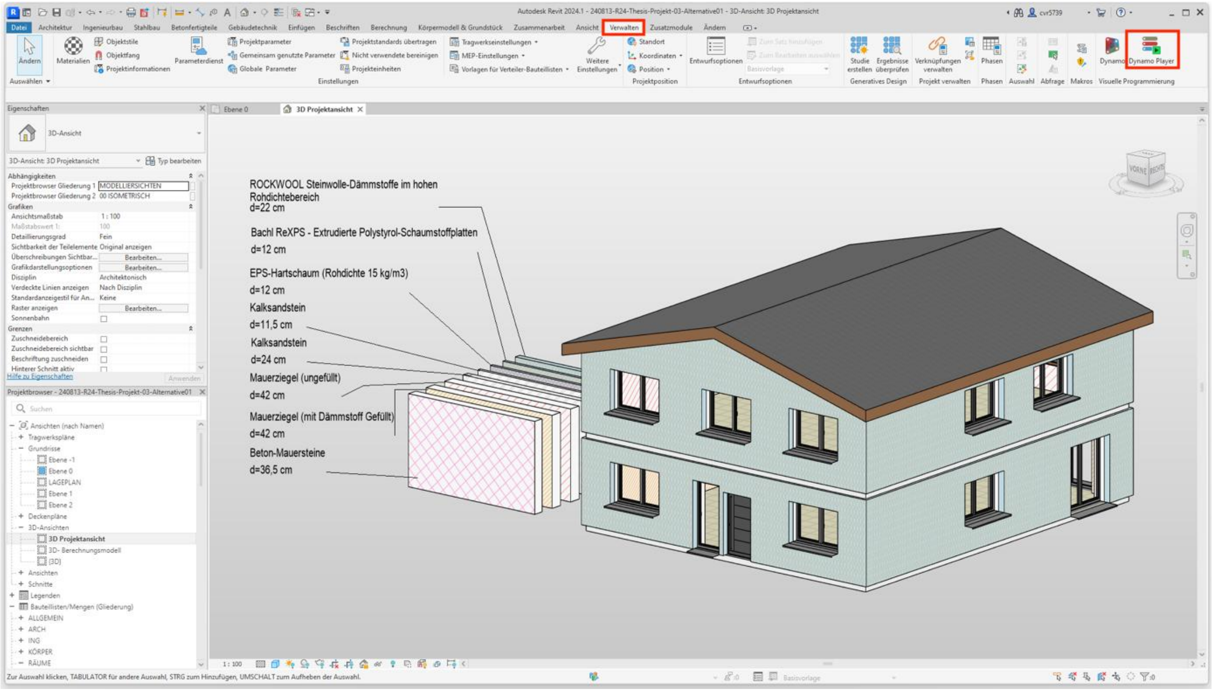

Figure 6: Digital building model for validation

To run the Dynamo script for the sustainability assessment, the ready-made script ‘Sustainability assessment’ is started with the Dynamo player in Revit. Here, the path to the file with the ecological parameters from ÖKOBAUDAT is stored. The prototype now accesses the data from the building model and links it with the data from the ÖKOBAUDAT file. The results per sustainability dimension and the values of the individual indicators are then listed. If required, the weighting of the sustainability dimensions can also be specified here. As can be seen in the following Figure 7, the weighted result of the dimensions and the overall degree of fulfillment of 58% rated as “neutral” are displayed.

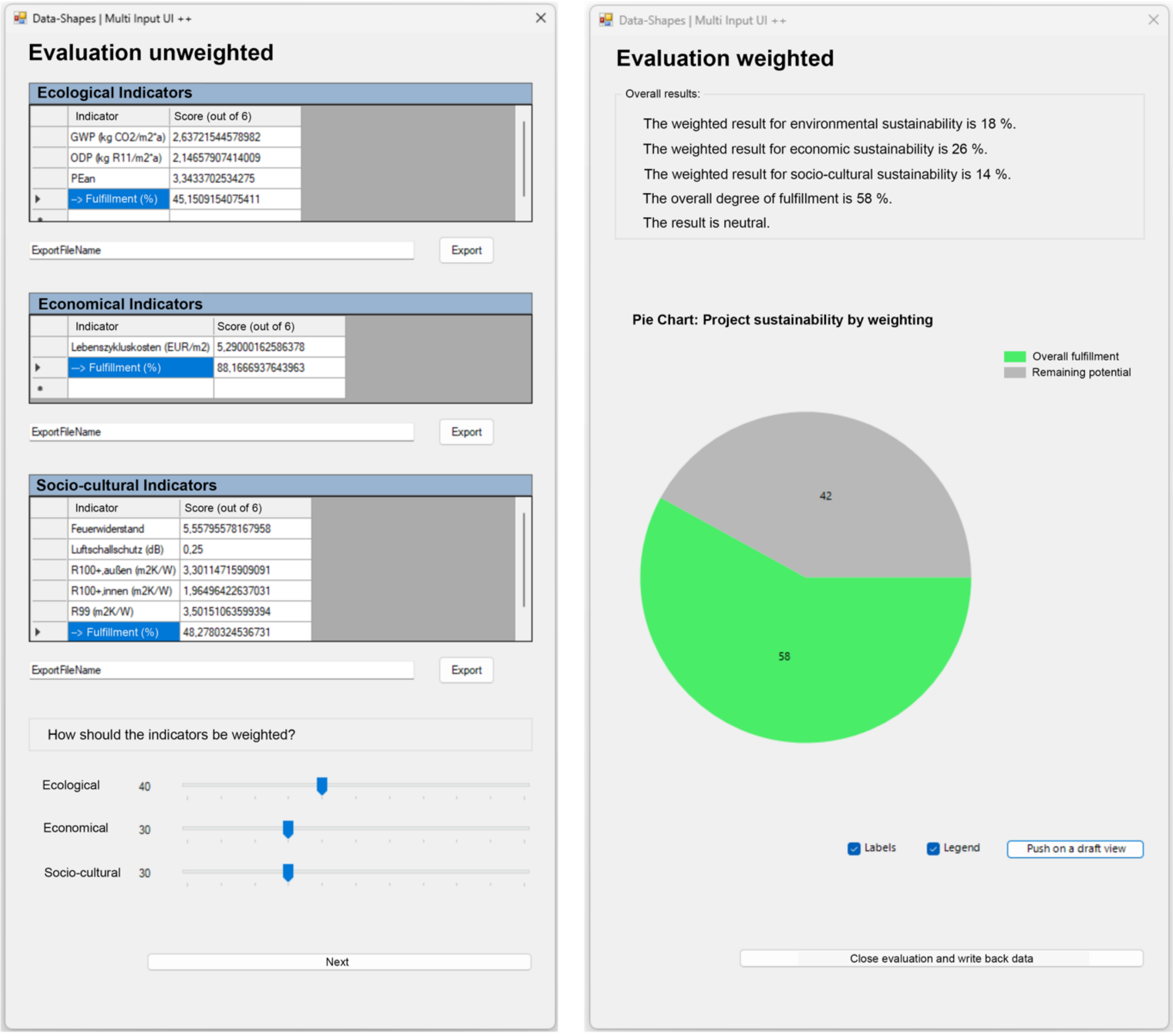

Figure 7: Evaluated sustainability calculation in Dynamo

Once the sustainability assessment has been carried out and the assessment visualized, the process is complete. This process can be repeated with different materials until the optimum sustainability result is achieved. Finally, the “Close evaluation and write back data” button can be selected to document the results. Here, the current status of the sustainability assessment is saved in the model and enriched with the project information. This ensures that the sustainability footprint of the building is also retained when exporting to the manufacturer-neutral IFC format. Figure 8 shows the information written back into the model.

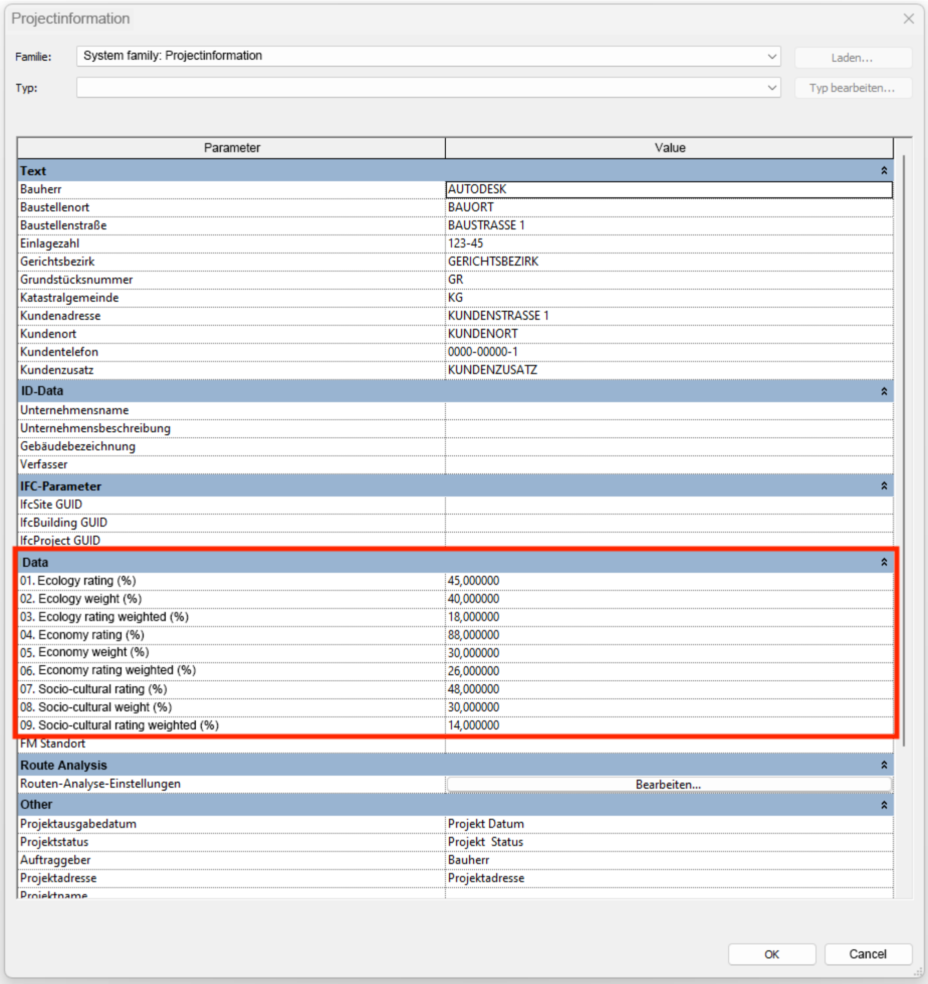

Figure 8: Automated backtracking of sustainability assessment results into the BIM model via Dynamo

6. Discussion

Efforts to make buildings more environmentally sustainable should not focus solely on ecological factors. Rather, the other sustainability dimensions such as economy and social requirements should also be included in the assessment, as every decision can have a positive or negative impact on individual indicators. At the same time, legal standards and various assessment systems for sustainability make it difficult to plan ideal buildings. Intuitive, simple and fast methods are therefore needed to make this planning process easier and more efficient. This study, with its focus on the sustainability assessment of building construction, provides a solid basis for this. In order to answer the research questions formulated at the beginning, the results are analyzed and critically examined below.

The first question focuses on the specific indicators relevant for evaluating environmental, economic, and social sustainability. A total of 16 indicators have been identified, primarily concentrating on the analysis of walls. However, a comprehensive assessment requires consideration of additional indicators related to the entire building structure. For example, energy efficiency is only taken into account using selected indicators with a focus on the walls, while other building systems are left out. Similarly, not all potentially relevant indicators are covered, as the focus is on the walls of a building. However, the system offers the possibility of expanding the indicators and thus taking additional aspects under consideration.

The second research question explores how sustainability data can be integrated into digital building models. The standardized enrichment of the model provides a solid foundation by consolidating all information in one place. However, initial standardization is necessary, which involves extra effort. Utilizing sustainability data from a database offers a promising approach to linking manufacturer-specific or generic data. Currently, the connection to external data sources is static, meaning that no automatic updates are possible. Dynamic integration of new data can help to further increase the flexibility and timeliness of the approach

The third research question examines how to interpret and visualize the results of digital building model analyses in order to ensure practical applicability and user-friendliness. The developed prototype requires only a few steps to perform a sustainability assessment: executing the Dynamo script and attaching the ÖKOBAUDAT file are sufficient to obtain both the assessment results and an interpretation of these results. At present, the validation has only been carried out on the walls of a building, which is only one part of a holistic assessment. Additional data from different systems are needed for a complete analysis.

With this prototype, however, it has been possible to bring together the relevant information on the building structure and thus reduce large parts of the manual calculation with the help of quantity extraction and linking with the appropriate data sets.

7. Conclusion and outlook

This paper presents an approach that enables a sustainability assessment for the construction of a building, considering environmental, economic and social aspects without the need for expert knowledge of sustainability assessments. For this purpose, a prototype was developed that carries out an automated assessment in just a few steps using a single file. A total of 16 indicators are used, which are taken from the BNB assessment system. The economic and social indicators are assigned to the objects in the digital model using a standardized material library. Ecological data in the form of EPDs is taken from ÖKOBAUDAT and automatically assigned to the components. The weighting of the sustainability dimensions can be adjusted according to the client's requirements to enable a flexible assessment. The results are then returned to the system and saved in the model. The prototype was validated using a digital building model with a focus on the requirements of the walls so that a successful sustainability assessment can be carried out. It shows that it is possible to carry out a simple sustainability assessment of the building if certain information is systematically integrated. Not only the ecological sustainability is assessed, but also the economic and social aspects.

Future work should precisely examine the core indicators of building construction and their interactions to determine the extent to which they influence the building and how they can be considered for a holistic sustainability assessment. In addition, specific indicators at building level need to be identified and implemented to ensure a comprehensive assessment for the whole building. The sustainability focus areas can then also be analyzed from various perspectives and ultimately optimized.

Also highly relevant is centralized data storage. If all the information required for the assessment is available in one place without having to rely on different databases or manual input, a sustainability assessment could be carried out largely independently of different model quality criteria. Although database platforms such as ÖKOBAUDAT already provide data on construction products, a standardized, central database that includes economic and social aspects in addition to ecological information is still lacking.

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