Function-based system modelling to structure sustainability of buildings

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A reduction of harmful environmental impacts regarding sustainable building design is challenging the real estate industry. Achieving this reduction, it is necessary to assess sustainable building design. Such assessments are mainly structured as a system of independent criteria and disciplines. These common procedures consume essentially time and resources. All buildings can be described as a system with different interactions to the environment. Relevant interactions for a sustainable environment can be systematically identified and modelled as sustainability functions. This approach aims to develop a function-based system by structuring criteria for an optimized assessment. Derived functions, like heat insulation and sun protection, indicate technical causes for the environmental impact for a better comprehensibility. The outcome of this paper supports further developments to assess the quality of sustainable design in the real estate environment.

1. Introduction

Sustainable building design for new and existing buildings is still one of the main objectives to reduce harmful environmental impacts caused by real estate industry. In order to achieve this objective, it is required to evaluate sustainable building design. Building design in this context means design and construction characteristics of buildings and building planning. An assessment of sustainable building design needs to cover many different impacts to the overall environment.

1.1. Current situation and problem definition

A sustainability assessment requires a multi-criterial analysis to reflect the high amount of sustainability impacts which are related to sustainable building design. Most multi-criterial sustainability assessments are based on ratings or benefit analyses [1]. From this perception a sustainability assessment is fragmented in different single evaluations and therefore the assessment procedure is separated into disciplines. These procedures result in complex time-consuming assessment methods.

1.2. Objective

The objective of this research is structuring assessment criteria in a function-based system. This function-based system aims to support an appropriate selection of indicators for the actual scope of application. For this intention, the structure is required to be suitable for a flexible demand of planning processes as well as real estate management processes.
2. Approaches for structuring criteria

The considered approaches are related to criteria sets of sustainability assessment methods. All findings focus on appropriate concepts of structuring criteria with adaptable complexity in application. Despite different problems and intentions, publications in literature review show various ways to establish a flexible set of criteria and less complex criteria structure [2].

A common methodology to structure criteria is a top-down approach. An international research project initiated by VTT Technical Research Centre of Finland uses a top-down approach which can be implemented from top to down with a gradual increasing level of detail [3]. The same research initiative demonstrates an approach defining grades with classes of descriptive criteria [3]. A reduction of sustainability criteria to amount key criteria by grouping and filtering is presented by C Schneider [4] and M Koschlik [5]. Furthermore, various approaches focus on system developments based on evaluations of redundancies and interdependencies [6][4]. T Lützkendorf suggests an element-method by dividing the building design into main construction parts for a faster indication of environmental aspects [7].

The literature review shows different approaches to structure sustainability for assessment requirements. A holistic function-based system modeling is not provided in the state-of-the-art research. Nevertheless, system approaches [6][4] which deliver additional operable information derived from established system views and top-down approaches [3] offer basic concepts for a function-based system modeling.

3. Development of a function-based system

3.1. Idea

Every building provides basic functions to meet the needs of various stakeholders. These basic functions recur to every building with the same type of use. Functions are defined as a contribution of buildings to protect or promote areas of protection and impact categories like Energy Resources, Drinking Water, Flexibility and Safety, [1][9]. The impact categories are connected to building specific targets found in sustainable development goals (SDG) like Responsible Consumption and Production and Good Health and Well-being which are announced by United Nations [10]. Functions provide information about the mechanism between sustainable building design and impact categories and create a constant cause-oriented assessment basis for an individual specification of indicators to measure sustainability.

3.2. Methodical procedure

To structure a function-based system a consequent methodology is required. The proposed methodology uses a top-down approach:

1. Defining affected impact categories for the scope of assessment for the top level
2. Connecting system elements of sustainable building design and each impact category from a system-oriented perspective
3. Deriving interdependencies between system elements for determining functional contributions of sustainable building design
4. Arranging these functions top-down in a logical and hierarchical way until a level of assessable criteria is found
3.3. General function-based structure for sustainability assessments

A function-based assessment structure which is the result of the described procedures arranges criteria by logical contribution of building design to sustainability. Starting by an impact category, like Energy Resources, functions leads to the adequate level of measuring. The function-based hierarchy supports procedures for selecting indicators in an appropriate level within the assessment structure.

3.4 Examples of a function-based assessment structure

The function-based assessment structure is explained by the impact category Energy Resources which is mainly connected to the SDG no. 7 Affordable and Clean Energy (7.2 and 7.3), no. 8 Decent work and Economic Growth (8.4) and no. 12 Responsible Consumption and Production (12.2). By deriving interdependencies between sustainable building design and Energy Resources three main functions has been derived: Reduction of Energy Demand, Optimize Energy Supply and Using Renewable Energy (see Level X in Figure 1).

![Figure 1: Function-based assessment structure for impact category Energy Resources](image)

![Figure 2: Function-based assessment structure for impact category Physical Comfort](image)
Arranging these functions from top to down leads to the next levels. For example, a Reduction of Energy Demand is mainly a function of Holding Indoor Temperatures, which is then again, a function of Heat Insulation and Sun Protection of buildings. Heat Transmission and Heat Loss Ventilation are the essential functions for the higher function Heat Insulation. The exemplary function-based assessment structure is shown in figure 1. Figure 2 demonstrates the assessment structure for the impact category Physical Comfort in the same way. The assessment structure also clearly indicates existing connections between different impact categories, which can be seen by the function Hold Indoor Temperatures. This function is part of assessment structure for Energy Resources as well.

4. Conclusion and future work

The proposed research focuses on structuring assessment criteria in a function-based system. In literature review different approaches were identified to establish flexible and less complex sets of criteria for an individual demand, while a holistic function-based assessment structure, which arranges criteria by logical contribution of building design to sustainability is not provided. The function-based approach indicates technical causes for the environmental impact and creates comprehension about essential characteristics for sustainable building design. The hieratical function-based assessment structure, which was exemplary shown for Energy Resources and Thermal Comfort, are adaptable for all impact categories. The presented structure of the function-based system supports the selection of measuring levels and indicators.

However, for some impact categories, the derived functions lead to criteria with limited measurability. For example, the Aesthetic Value of Buildings can be described in functions, like Rhythm, Proportionality, Tension and Harmony [8], but measurable indicators behind these functions are very restricted. Further research is required to improve the connection of building design functions to available measurements and benchmarks.

References

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