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Visualizing interdependencies among sustainability criteria to support multicriteria decision-making processes in building design

Marco Scherz[a], Bernd Markus Zunk[b], Alexander Passer[a] *, Helmuth Kreiner[a]

[a] *Working Group Sustainable Construction, Institute of Technology and Testing of Construction Materials, Graz University of Technology, Inffeldgasse 24 – A-8010 Graz*

[b] *Working Group Industrial Marketing, Purchasing and Supply Management, Institute of Business Economics and Industrial Sociology, Graz University of Technology, Kopernikusgasse 24/II – A-8010 Graz*

* Corresponding author. Tel.: +43 316 873 7153; *E-mail address:* alexander.passer@tugraz.at

Abstract

It becomes increasingly challenging to follow decision-making processes while designing sustainable buildings as various sustainability criteria must be operationalized to maintain the optimal integral building performance over its whole life-cycle. Because it is difficult to manage the numerous interdependencies between sustainability criteria as well as their relationships to "traditional" design criteria such as cost, decision-makers are forced to gain in-depth knowledge about the impact of their actions by applying a decision-making process that relies on multiple criteria. In this paper, we introduce a systemic and stepwise management approach based on the literature that can be taken to visualize interdependencies between various building design criteria. This may help decision-makers reduce risk during the management process. Therefore, we present the results of a causal loop investigation. We used causal loop investigations founded on a selection of sustainability evaluation criteria among various building design criteria to identify possible conflicts and identify synergies regarding these sustainability criteria. As a result, we have developed a methodology that - can be used to visualize relevant interdependencies among sustainability criteria in building design, depending on the quality levels of the expected functional and technical equivalents.

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1. Introduction

The unique designs of buildings and individual preferences lead to new challenges for decision-makers in construction industry (e.g., architects, engineers). Numerous criteria and their interdependencies (e.g., architecture, statics, building physics and facility management) must be considered. In addition to the three classical pillars of sustainability (ecological, economic and social), functional and technical requirements also must be considered in the building design for the implementation of sustainable construction.

In the current building design practice, sustainability criteria are not frequently taken into account or they are forgotten due to their numerous dynamic interdependencies and the effects these cause. Because of the enormous amounts of time and costs involved, decision-makers cannot consider all of the sustainability criteria which are, for example, recorded in building certification systems.

Furthermore, it is currently not possible to support project participants who are not involved in the construction industry in the decision-making process in reasonable amounts of time. Because we currently lack tools that we can use to support multicriteria decision-making methods (MCDM) in construction industry, it is necessary to develop a framework for a process model, which can be used to visualize the interdependencies among sustainability criteria in the building design. By using

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the process model framework described in this article, the decision-makers and those who support decision-makers can be given the opportunity to visualize the effects of their decisions during the early stages of a project.

This article is organized as follows. Section 2 includes a brief overview of relevant literature on sustainable construction, building certification systems and a systemic approach taken. In section 3, we introduce the applied methodology that we have proposed to analyze the interdependencies among sustainability criteria and modelling the process model framework. The results, including an application example, are provided in section 4 by. This article concludes with a short summary as well as an outlook and further research topics.

2. Overview of relevant literature

Sustainability in construction industry (i.e., the application of the principles of sustainable development [3]) plays a key role due to the material and energy flows and the associated environmental effects. As part of the efforts to develop measures for climate protection [8], for example, by improving energy and resource efficiency [27], the construction sector is also becoming more important due to the enormous amount of materials and energy it consumes [24]. When deriving sustainability criteria based on the environment protection goals of sustainable development [29], the dimensions of sustainability – including the functional and technical quality – should always be treated equally [17, 4, 15]. An increase in building quality can be achieved by considering and evaluating sustainability criteria during the early stages of building design [12].

Over the last two decades, various building certification systems have been developed and established [6, 32, 13, 2, 31]. However, their sustainability criteria have been allocated and weighted differently. Due to interdependencies among sustainability criteria in the building certification systems, the overwhelming number of users lack experience regarding their influence on the certification result [26]. For this reason, systemic interdependencies among building certification criteria are often neglected [1, 10, 18, 25].

Many researchers are asking methodical questions about the life-cycle-based sustainability analysis and the assessment process at the building level, as well as the operationalization of sustainable construction, by integrating these questions into the design process. It has become increasing relevant to effectively and efficiently integrate sustainable suppliers in the building design process [34]. To achieve the objectives of sustainable construction, research must be conducted on the integration of assessment methods into design and project control processes. Finally, the holistic requirements of sustainability on building tasks, which increase the complexity of decision-making processes can be summarized by the following essential, influential parameters [33, 21, 20, 9, 22]:

- Insufficient information
- Incomplete knowledge
- Numerous influencing factors
- High degree of crosslinking
- Diffuse goals and trade-offs
- Difficultly calculating risks
- Time pressure in decision-making

Furthermore, different preferences in the decision-making process may lead to trade-offs in the building design of projects. To holistically fulfill a sustainability criterion, it is necessary to fulfill several functional requirements. Current design decisions are usually reduced to an instantaneously-assessed functional requirement (e.g., energy efficiency) as part of the sustainability assessment of a building.

The assessment of individual sustainability criteria is an approach that is classified as a linear approach in the body of literature. Due to interdependencies among the criteria, the current linear approach is not sufficient for a holistic building assessment [21].

Therefore, systemic thinking has become increasingly important in building design processes in recent years [30, 5, 6]. Compared to analytical thinking, systemic thinking is contextual. This means that a system can only be understood if it is set in the context as a whole. The human processing capacity is limited by structures that are defined by four related variables [14]. Therefore, the difficulties inherent in the development of systemic approaches are related to the challenges humans experience while attempting to understand the interacting criteria. Construction projects involve an overwhelming multitude of influential criteria.

However, due to the multicriteria decision-making in the context of sustainability assessments, system theoretical approaches are becoming more important, for example, in the form of systems engineering and cybernetics in construction engineering [5, 16, 30]. Different systemic approaches are described in the literature [7, 28, 11, 26].

3. Applied methodology

We illustrate how to link sustainability criteria for building certification systems using the applied methodology described in this paper and define a goal based systemic approach by considering the described process model framework (section 3.4). To do so, we focus on holistic criteria sets in section 3.1 and provide an overview of the goal definition in section 3.2. In section 3.3, we outline the analytical method used for the chosen building certification system.

3.1. Holistic criteria set

Firstly, several building certification systems were analyzed. Based on a comparison made of different building certification systems, we concluded that the ÖGNI/DGNB criteria set is in accordance with the CENT/TC350 requirements and represents an advanced second-generation building certification system [19]. According to the ÖGNI/DGNB certification system, the criteria set used to assess the sustainability of buildings comprises more than 100 evaluation criteria. These criteria are referenced to assess the completed building comprehensively. In terms of its application to building design, the system is only conditionally suitable in its current form, for example, in the context of integral planning to determine the impact of decisions due to not considering the interdependencies among sustainability criteria.