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A new systemic approach to improve the sustainability performance of office buildings in the early design stage

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ABSTRACT

Different users and investors' project preferences, often lead to trade-offs during the early design phase of a project. Currently, decisions of design options and their technical measures are mainly reduced to an instantaneously assessed criterion (i.e. energy efficiency) within the sustainability assessment of buildings. Due to criteria interdependency, the current linear applied approach used in building certification neglects criteria trade-offs and is therefore only partly suitable for holistic building improvement processes. In order to fulfil stakeholder interests on the one hand and a high sustainability performance on the other, it is crucial to identify appropriate design measures. Based on the Austrian building certification system ÖGNI/DGNB, we applied a systemic approach for building sustainability-improvement, using a case study of a public office building in Graz, Austria. The main part of the study describes the important steps required for the systemic optimization of building sustainability. The method applied in this study allows the quantification of the relative influence and the identification of the individual optimization potential of design options on each single assessment criterion. The proposed systemic approach clearly demonstrated the improvement potential of the currently most developed building certification system considering the interdependency between the individual criteria.

1. Introduction

Transferring the principles of sustainable development [6] into the construction sector and the construction industry means introducing a change of paradigm with the challenge that there is no universally accepted definition and no unique solution for sustainable buildings [50–52,62]. The perception of sustainable buildings is changing over time and depends on the location. During the last two decades, various building sustainability assessment systems have been developed and established [4,11,21,56,58]. Building certification systems are considered to be appropriate tools for the evaluation of sustainability performance on buildings [42,45]. However the local context should be taken into account in building sustainability assessment schemes [44,52].

According to the CEN/TC 350 framework (sustainability of construction works [7–10]), sustainable buildings should fulfil environmental, social and economic as well as functional and technical aspects. In this context several articles deal with nearly zero energy standard buildings and discuss for example the influence of operational and embodied energy demand on their related impacts [5,13,14,24,25,27,33–37,47,59]. Thereby different users and investors' project preferences often lead to trade-offs during the design phase of a project. These trade-offs are caused by the optimization measures and their system interdependencies. For example, a system trade-off could occur while improving thermal comfort in winter and visual comfort, or if choosing a measure with decreased initial costs but with higher life cycle costs.

So far, the focus of building design optimization has mainly been laid on the reduction of the final energy demand in the operation phase of buildings, e.g. through increased insulation. Decisions on design options are therefore reduced to an instantaneously assessed criterion (i.e. energy efficiency) in the sustainability assessment process of buildings. This is caused by the current linear assessment approach for building certification of singular technical measures. In this case, the linear assessment approach is characterized by the coverage of only one dimension in the assessment of design measures (e.g. fulfilment of quantitative assessment goal of DGNB[1]/ÖGNI[2]/[39] criterion "thermal

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[1] German Sustainable Building Council (DGNB) – www.dgnb.de.
[2] The DGNB Certification System was adapted to national requirements by ÖGNI (Austrian Council for Sustainable Buildings) – www.ogni.at.

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comfort") without consideration of their environmental and/or economic impact. Thus the interdependency of other criteria and their influence on overall building performance is thereby often neglected, especially in early planning stages [2,18,28,46] although the ÖGNI certification system does provide minimum requirements in all assessment categories (e.g. economics, environmental, social, etc.), which are prerequisites for a high sustainability performance.

In contrast, systemic thinking is gaining more and more in interest in the last years [11,12,26,55]. Different systemic approaches in context to criteria-interdependencies are described in [15,20,49,54]. Using a systemic approach in multi-criteria assessments permits the modelling of the previously mentioned criteria interdependencies and the highlighting of system trade-offs. In order to fulfil stakeholder interests on one the hand and a high sustainability performance on the other, it is very important to identify appropriate measures, which improve the sustainability performance of buildings. Therefore, good knowledge of system effects triggered by design optimizations – according to certification systems – is essential. A previous review of current literature by Evins [17] show a wide range in studies regarding multi-objective optimization (covering works from 1990 to 2012). The investigated works focus on different system boundaries such as envelope design, including construction and form, configuration and control of building systems or the simulation of the whole building. Holistic approaches are associated with the coverage of the whole building by system simulations. The most common objectives are an optimized energy performance, several variations on cost objectives and an increased indoor environmental comfort. Current works reveal important aspects for a systemic improvement process for example such as consideration of stakeholder's preferences [3], regression analysis of design parameters [2], parametric system modelling [19], system behaviour of quality criteria [22] and influence of construction product characteristics on the results of building certification [61].

These current multi-optimization approaches are a good basis for systemic improvement of buildings but are only partly suitable for application to holistic building improvement using building certification systems. They do not permit an optimization approach covering both estimation of single measure influence on overall building sustainability and stakeholder objectives by highlighting their system interdependencies. A systemic approach to model and quantify the systemic effects caused by different design options has generally not been considered yet [31]. At present, there are no commercial tools that can analyze interdependencies in building sustainability improvement. Hence current approaches also focus on the optimization of single measures e.g. on floor on grade [1]. Although there are models and algorithms for holistic improvements of single parameters in practice, there is still a barrier to apply these methods in early planning stages. As stated in Hakkinen [23], organizational and procedural difficulties caused by the adoption of this new method hinder this application. Further commercial applications of complex improvement approaches require time, knowledge and resources that are recently significantly decreasing in the construction industry [17]. To conclude, there is a gap in current methods to enable the highlighting of systemic influence and the pros and cons of single measures regarding their sustainability optimization potential in building certification. Furthermore current sustainability assessment systems do not provide the highlighting of essential criteria interdependencies caused by optimization scenarios in early planning stages.

This article presents a new methodological approach leading to the integration of systems theory in the field of building assessments. We applied a systemic approach covering quantitative influence of criteria interdependency in building certification that provide indispensible information for the management of stakeholder preferences in early planning phases. By modelling the interdependencies of sustainability criteria the systemic behaviour of single optimization measures in context with building sustainability assessments can be highlighted.

2. Methods

The theoretical model for the systemic improvement of building performance basically combines building certification and system analysis.

Based on a comparison of several building certification systems, it can be concluded that the ÖGNI criteria set represents an advanced level of sustainable building certification system of the so-called 2nd generation [29] and in accordance with the CEN/TC 350 requirements. Due to this, a ÖGNI assessment system was applied for further investigations. The application of building certification systems for the improvement of a building's sustainability performance is generally afflicted with numerous influencing factors, target trade-offs and a high degree of cross-linking [60]. In order to permit early estimations of the holistic influence and system trade offs caused by improvement process in early design stages or due to project changes, the presented approach combines the assessment method of ÖGNI building certification method with Vester's sensitivity model [31,55]. The system "building" is thereby described as open, dynamic system. In this context the term "dynamic" comprises life cycle perspective and criteria trade off, the term "open" is associated with divergent stakeholder preferences. The system provides a holistic optimization approach for new office buildings. In detail, the spatial system boundaries covers the whole building by including the construction and building related services (i.e. energy supply). The reference study period is set with 50 years covering the life cycle stages before use, use and after use.

In this study, a first general estimation of suitable criteria for systemic optimization is carried out by parts of the sensitivity model defined by Vester [55]. System effects are further modelled using qualitative network analysis for the detailed management of the resulting multi-criteria decision problem. The influence of single measures on the overall as well as on the pre-defined stakeholder targets are finally carried out by a semi-quantitative calculation algorithm based on the applied certification system. Thereby the influence of each measure-variant is compared to a reference measure, which represents minimum requirements (i.e. legal requirements, initial costs and energy performance). With regard to European Union energy efficiency 2020-targets [16], several energy efficiency measures (in total 25 alternatives) have been analyzed (e.g. Life Cycle Assessment – LCA and Life Cycle Cost Assessment – LCCA performance and the social impact) and presented for the first evaluation of the approach. Due to the important role of the building envelope in context to LCA and LCCA, energetic performance on the overall certification result the focus has been laid on the improvement of the building envelope.

The ÖGNI building certification method permits good assessment of the direct influence of single measures on the optimized criterion. However, the management of appropriate estimations of possible system trade-offs caused by the optimization process is not currently a part of the assessment procedure. Thus the presented systemic building sustainability improvement method includes six steps shown in Fig. 1. The systemic approach is thereby divided into three areas. This study focuses on step 1 (which is independent of the applied case study) and step 2 to step 5 (which are steps related to the presented case study). The final step gives an outlook and presents current research work in this context. The descriptions made in chapter 3 follow this process.