Multi-criteria decision making for sustainable building parts

Kathrin Theilig – TUM School of Engineering and Design
Department of Civil and Environmental Engineering

Background

In addressing climate change and its impacts, a significant reduction in greenhouse gas emissions is necessary. Addressing global climate goals, the EU aims for a net reduction of greenhouse gas emissions of at least 55 per cent by 2030 compared to 1990 levels [1]. The building sector plays a critical role in the transition to a climate-neutral and circular economy, as it is a major source of greenhouse gas emissions and resource consumption: In 2022, buildings were responsible for 37 per cent of global energy and process-related carbon dioxide (CO_2) [2].

In the design of building parts, planners must consider lots of aspects simultaneously, see Fig. 1 and Fig. 2. In addition to climate change, there are many quantitative (e.g., global warming potential, other environmental impacts) and qualitive criteria (e.g., user preferences). With an increase of energy retrofits and an operational energy use with renewable energies, embodied emissions are getting more important. Hence, a life cycle-based approach is essential and an approach for multi-criteria decision making (MCDM) for planners is needed [3].

Focus on single criteria

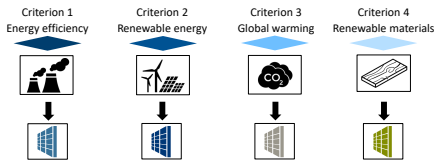

Fig. 1 Consideration of exemplary, single criteria in the design of building parts (own representation, icons from noun project).

Multi-criteria decision making (MCDM)

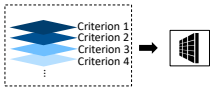

Fig. 2 Multi-criteria decision making in the design of building parts (own representation, icons from noun project).

Research questions

This dissertation aims to:

- Identify methods of multi-criteria decision making (MCDM) which are suitable for the selection of building parts
- Examine how MCDM methods can be used in the planning process of building parts
- Evaluate the influence of the selection and weighting of climate and environmental protection criteria on the result of MCDM
- Compare the results of different MCDM methods
- Discover the contribution of MCDM to the selection of climate and environmentally friendly building parts

Methodology

Within this research, life cycle assessment (LCA) and MCDM are combined. So far, relevant environmental criteria for building parts were identified throughout a systematic literature review. In addition, MCDM methods in the built environment were analyzed. For various building parts from research projects, selected criteria were determined and implemented in different MCDM methods to show the ranking of the building parts' performance and hence the best alternative(s) [3, 4].

Results

As displayed in [3], environmental criteria for building parts can be categorized into four main areas: (i) emissions, (ii) energy, (iii) resources, and (iv) circularity. In total, 26 criteria regarding environmental protection are identified. The global warming potential is rated as extremely important, yet not the only criterion.

As for MCDM methods, the Analytic Hierarchy Process (AHP) is widely used. However, a standardized method for planning processes has yet to be established. A case study comparing the Analytic Network Process (ANP) and AHP shows similar rankings for the best and worst alternatives when selecting the optimal ceiling structure [3].

Another suitable MCDM method is the utility analysis. The general procedure is shown in Fig. 3 and was applied for the selection of the best timber constructions in the TUM research project EDUwood (for more information, see https://www.cee.ed.tum.de/en/enpb/research/current-research-projects/eduwood/). For practicability reasons, not only environmental criteria were considered, but also building physics, structural aspects, and material costs. Comparing the costs to the results of the utility analysis is called cost-utility analysis. The comparison is especially helpful when cost limits are critical, as the best alternative (high utility value and low costs) can simply be identified. [4]

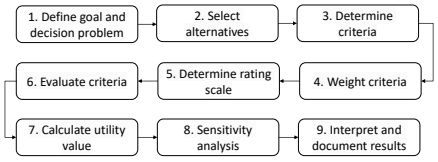

Fig. 3 General procedure of the utility analysis (adopted from [4]).

To achieve sustainable buildings and building parts, designers must consider a wide range of criteria. The developed approach as shown in Fig. 4 helps to structure the decision-making problem and navigate through the resulting complexity when considering multiple criteria simultaneously.

Key Messages

- Multi-criteria decision making (MCDM) methods support complex decision-making in building design.
- Combining life cycle assessment and MCDM is crucial to achieving a high impact on the environmental quality of buildings and building parts.
- The ranking of alternatives (building parts) depends on the choice of criteria and their weighting. Thus, apparently objective decisions are based on subjective assessments Therefore, a transparent documentation and sensitivity/scenario analyses are crucial.
- Alternatives listed in the ranking must be examined in relation to (local) building regulations and practices.
- The comparison of different MCDM methods regarding their applicability, transparency, and ranking of alternatives is planned in further studies.

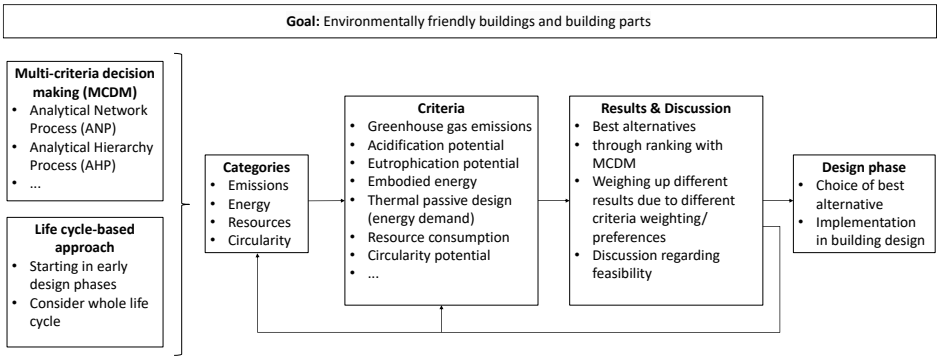

Fig. 4 Systematic approach for life cycle-based MCDM in the planning and design process with the goal of environmentally-friendly buildings and building parts (adjusted from [3]).

Supervision

Prof. Dr.-Ing. Werner Lang, Chair of Energy Efficient and Sustainable Design and Building, Technical University of Munich
Prof. Dr.-Ing. Jutta Albus, Department EKNB - Design and Construction/Sustainable Building, Bochum University of Applied Sciences

Sources

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WE WALK THE TALK

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