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Choosing by advantages: A case study for selecting an HVAC system for a net zero energy museum

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ABSTRACT

Choosing a building system is not an easy task, especially when designers are concerned about the social and environmental impacts of their choices, as in the case of a net zero energy (NZE) building. In addition, economic constraints are commonly misunderstood so that all too often decisions are based on what is cheaper upfront and do not take the life-cycle cost into account. Moreover, the interaction with increasing numbers of stakeholders makes decision-making even more complex. While decisions can be supported by decision-making methods, in practice many are made without a formal method or discussion, which often generates conflict and waste in the design process. Few designers know how to incorporate social, environmental and economical factors when making a decision. This research fills the literature gap and provides practical advice for practitioners by demonstrating the application of a method called choosing by advantages (CBA) in order to create transparent and collaborative environments in which to make decisions. This paper presents a detailed case study of choosing an HVAC system for a NZE building in California. It provides evidence that CBA supports the choosing problem by integrating multiple perspectives, creating transparency, separating "value" from cost, and clearly documenting the decision rationale.

1. Introduction

Commercial building design is characteristically group decision-making, in which many internal stakeholders are involved (owner, architect, structural engineer, mechanical engineer, electrical engineer, etc. and sometimes users). They make hundreds of decisions in different phases of the design process, with different levels of detail [1]. The problem is that the decision process is not necessarily well managed or understood in the architecture, engineering, and construction (AEC) industry. AEC practitioners lack education and training in the use of multi-criteria decision-making (MDCM) methods, and make decisions without a full understanding of all the technical problems involved ([31]).

The decision process can be characterized as an iterative process described by the following steps (1) *identify client needs*, (2) *set design goals*, (3) *generate or identify alternatives*, (4) *collect data*, (5) *choose an alternative*, and (6) *Reconsider* (adapted from Ref. [2]).

This paper focuses on step five, where the design team needs to understand the differences between alternatives, consider the decision context, and choose the best one according to the available resources (e.g., cost and schedule constraints). Roy [3] describes the choosing problem as selecting one and only one action or alternative (or a combination of these). The problem lies in choosing the best of all.

A net zero energy (NZE) building produces as much energy as it consumes when measured on site on a yearly basis (according to [32] definitions). It is by definition a sustainable building. Designing an NZE building is challenging, especially in terms of coordination between designers in order to ensure that building systems work effectively and efficiently together. Decisions in this context involve quantitative and qualitative factors. Since the design team needs to

Abbreviations: AEC, architecture, engineering, and construction; AHP, analytical hierarchy process; CBA, choosing by advantages; IofA, importance of advantage; MCDM, multi-criteria decision-making; NZE, net zero energy building; WRC, weighting rating and calculating.

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consider multiple factors when making decisions, a MCDM method can help in creating transparency, building consensus, and in continuous learning. Using such a method, the design team can provide a clear and shared rationale for arguing in favor of one alternative compared to others.

Decision-making methods influence decision outcomes [2]. In fact, different decision-making methods may lead to different decisions. The problem is that the literature does not provide much if any guidelines for practitioners to select a MCDM method in this context. This paper fills the literature gap by testing choosing by advantages (CBA) and providing practical advice for practitioners building on past research [4,5] that demonstrated that CBA is superior than most traditionally used MCDM methods such as the analytical hierarchy process (AHP) and weighting, rating and calculating (WRC).

In this paper we apply the tabular method of CBA [2] to overcome the challenge of managing information when selecting a sustainable building system, while accounting for the perspectives of multiple stakeholders representing different companies, as well as the final users. This case study applies choosing by advantages (CBA) to a real project, namely choosing an HVAC system for a NZE museum in San Francisco, California.

The objective of this case is to demonstrate the applicability of CBA in a real design project. This case study represents a complex decision that concerns choosing a building system that has several interdependencies with other building systems. In addition, the authors had the opportunity to assess the quality of the chosen design by interviewing the people in charge of operating the building since the project was finishing construction at the time the research was conducted.

2. Research questions and methodology

This paper expands on preliminary studies comparing CBA with other MCDMs [4,5]. These studies recommended the use of CBA for its ability to provide transparency, support consensus building, and allow for continuous improvement. However, documented applications of CBA for selecting sustainable systems are almost non-existent in the scientific research literature. Additionally, the selection of HVAC systems is seldom seen as a group decision-making process. Studies presenting MCDM methods to choose HVAC systems based on energy efficiency, thermal comfort, and costs (e.g., [6–13]), rarely consider other stakeholders' perspectives, such as those of owners, architects, and building operators. This paper fills that gap by providing an example that demonstrates how the CBA Tabular Method helps in making various stakeholder's perspectives transparent in the decision-making process.

In addition, making a decision while considering both first cost and life-cycle cost, as well as economic and social factors is not well understood by AEC practitioners nor well-described in the literature. In fact, several cases in the literature (e.g., [14–19]) treat first cost and life-cycle cost, as well as environmental and social factors equally. In contrast, in CBA cost is a constraint not a 'value', therefore, it is not mixed with factors that are used to gauge value.

This paper seeks to answer the following research question: How does CBA support the building system choice problem when considering multiple factors representing sustainability issues in addition to first cost and life-cycle cost?

In order to answer this question, first, the authors conducted a literature study of the CBA method [2], and studied in-depth applications of CBA in the AEC industry (e.g., [4,5,20–25]). Second, the authors followed a case study methodology as recommended by Yin [26] and Flyvbjerg [27,28], in order to explore the implementation of CBA to decide on an HVAC building system using a real construction project, designer's preferences, and market data.

The next section describes the protocol followed in this case study. At the time of the study, the actual decision regarding the HVAC system had already been made. Therefore, this case retrospectively considers how the CBA decision-making method could have been applied. The researcher (first author) conducted several interviews to understand the project context and to obtain feedback from the design team, building operator and users about their design decision.

2.1. Case study protocol

The following case-study protocol describes the steps that the researcher followed to test the use of CBA on this project.

1. Obtained public data to understand the project background.
2. Conducted interviews with several stakeholders including the project director of the museum who represented the owner, the mechanical engineers, and the engineers in charge of building operation. The interviews were conducted to better understand the perspectives that went into the general decision-making process and to identify a specific design decision that could be used as a case study. The researcher showed the interviewees examples of CBA applications to assist them in identifying opportunities where application of this method might have been valuable for the project.
3. Decided to study the HVAC system because the decision was relevant for the project, involved multiple stakeholders, and impacted multiple building systems.
4. Gathered detailed information about the alternative HVAC systems originally considered and their interaction with other building systems. Access to analyses and presentations was facilitated by Peter Rumsey, mechanical engineer for the project, co-author of the paper, and CEO of Point Energy Innovations, formerly with the Integral Group.
5. Identified attributes for applying CBA to choose one of three HVAC alternatives.
6. Prepared an example of a CBA application using the information available.
7. Wrote a report on the case study and sent it to the interviewees for feedback.
8. Incorporated feedback in the CBA application and conclusions.

The next section presents CBA.

2.2. Choosing by advantages

CBA is a decision-making system that supports sound decision-making using comparisons of advantages among alternatives. Suhr developed the system while working in the US Forest Service. Table 1 presents CBA definitions adapted from Suhr [2].

In CBA, decisions are based solely on advantages (rather than advantages and disadvantages), thereby avoiding double counting. Once the advantages are defined, stakeholders need to assess the importance of these advantages by making comparisons amongst them. Weights should be assigned based specifically on the importance of these advantages, instead of on the importance of general criteria, factors, or other types of data [2], p. 80. The CBA decision-making process includes 7 steps (Fig. 1).

In step 1, stakeholders choose alternatives likely to yield important advantages over other alternatives. In step 2, they define factors with the purpose of differentiating between alternatives. In step 3, stakeholders agree on the criteria within each factor. Criteria are used to evaluate attributes of alternatives. A criterion is a decision rule that expresses express either a desire (want criterion) or a requirement (must criterion). Alternatives that do not comply with a must criterion are not considered in the following steps.