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A decision making support tool for selecting green building certification credits based on project delivery attributes

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ABSTRACT

The Green Building (GB) certification process embodies detailed requirements and specifications that lead to additional tasks for project teams, which increases complexity levels of the entire project delivery process. Previous studies show that if the GB certification credits to be fulfilled are selected without considering project team attributes, then elevated levels of time, money, and labor could get wasted while attempting to meet the additional requirements of GB certification. The aim of this study is to develop a multi-attribute decision making (MADM) support tool to be used by GB experts to select the appropriate GB certification credits based on the project team attributes. The developed framework with relative weights assigned via the Delphi method was used to perform the MADM analysis, which employs the hybrid use of the Multi Attribute Utility Technique (MAUT) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). This paper presents the developed MADM tool (i.e., GB-CS tool) and the relative weights of the attributes that were determined following expert opinions. To validate the tool, a case study was conducted at a LEED-registered residential project. The results show that the GB-CS Tool was successful in ranking the GB certification credits to be selected. This hybrid MADM tool can be used for preventing disruptions and bottlenecks in GB project delivery processes by assisting the owners/GB consultants in effectively selecting suitable GB certification credits based on the project team attributes. Thus, with the assistance of the GB-CS tool, root causes of waste can be mitigated in the GB project delivery process, decreasing associated hidden costs.

1. Introduction

A “green building” (GB) or a “sustainable building” is a high performance building that is designed and constructed in a resource-efficient manner to preserve energy, water, materials, and land throughout its life cycle while providing healthy environments for its occupants through the application of “environmental” principles [1,2]. GB projects require multiple technical disciplines to have elevated levels of interdependency and interconnectedness [3–5]. Basically, structural, mechanical, electrical, and architectural systems need to function together in systematic unity to form a project that is “green” [6]. This interconnected and interdependent nature of GB projects leads to certain complexities and results in additional management challenges [7–9].

The GB certification process embodies detailed requirements and specifications that lead to additional tasks for the project team (i.e., detailed documentation and advanced green system design and implementation) that elevate the level of complexity for the whole project delivery process [7,10]. This relatively novel concept results in some unique challenges for project teams and decrease productivity throughout design and construction phases of GB project delivery. This may prevent achievement of project objectives related to time, cost and sustainability [7,11–14].

To achieve GB certification for a project, the first step is to select appropriate credits to be met in the project from among a large set of credits categorized under the selected GB rating system. Selecting credits that qualify the project for GB certification is a pivotal decision to achieve the sustainability objectives of the project [15]. Former studies have shown that architecture, engineering and construction (AEC) professionals experience a great deal of difficulty in selecting the certification credits to be implemented in new construction projects because of several uncertainties in the selection process [8,16–22]. Once the credits are

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selected, the requirements of these chosen credits must be fulfilled throughout the project. Previous studies have shown that if the selected GB certification credits were not appropriate for the project team attributes, then increased levels of time, money, and labor could be wasted [7–10,23]. Therefore, selection of GB certification credits is a crucial process that determines the success of the project. To promoting the sustainability objectives throughout optimization of the GB certification credit selection process, several researchers recommended using a well-structured decision making support tool that aid in preventing various decision-making problem [9,15,16,19,24,25].

In the study explained in this paper, it is proposed that when selecting GB certification credits, attributes related to the project team (e.g., qualification of project teams) need to be considered, since they noticeably affect the project's success in terms of time, cost, and sustainability [5,7,9,11,12,14]. Moreover, according to the findings of the authors' previous study, the most critical factors that ensure the success of GB projects are related to project team attributes [26]. However, the studies that aimed to select appropriate credits in a GB project did not include the existing attributes of the project team in the selection criteria [15–18,20–22,27,28]. This study aims to fill this gap and the objective of this study is to develop a multi-attribute decision making (MADM) support tool that can be used by GB consultants/owners to effectively select the GB certification credits based on the project team attributes. This MADM tool, namely the Green Building-Credit Selection (GB-CS) Tool, is built on Leadership in Energy and Environmental Design – New Construction (LEED NC) within the Building Design and Construction (LEED BD + C) rating system. The MADM analysis is used to select the appropriate GB certification credits in a project based on relative weights of the project team attributes and scores assigned in the project to the project team attributes for each credit. A case study was performed showing how the developed tool can be used, and the credits and their rankings obtained from the GB-CS tool were compared with the credits that were actually selected by the LEED team in the case study.

2. Literature review

Previous studies developed models or tools to assist in selecting the appropriate GB credits (e.g., LEED, BREEAM). Some of those studies adopted case based reasoning (CBR) approach [17,18,20,24], a few of them employed Building Information Modelling (BIM) driven platforms [22,28], and some performed multi-criteria decision-making (MCDM) techniques such as Analytical Hierarchical Process (AHP) and ELECTRE [15,16] for selecting the appropriate GB certification credits.

One of the studies that adopted CBR approach focused on selection of LEED v3 Existing Buildings Rating System credits based on the project information (i.e., location, owner type, gross floor area and target level) and the surrounding climatic factor using data mining techniques [19]. Similarly, another CBR based study explored the credit bundles of LEED for Existing Building considering their correlation relationships [26]. Other two CBR based studies analyzed LEED v3 NC credit achievements in previous projects using data driven techniques [17,18]. While one of them adopted CBR approach to provide case studies of similar certified GB projects to select the target LEED credits [17], the other one studied on the achievement of individual credits using percentage of average score (PAS) and the achievement of the related credits using classification based on Multiple Association Rules (CMAR) [18].

The BIM driven studies conducted by Kasim et al. aimed at developing a BREEAM or LEED based approach for evaluating sustainable design alternatives [22,28]. Among the studies that used MCDM techniques for selecting LEED credits, Sulochana et al. [16] intended to develop a decision making model using AHP and Monte-Carlo simulation techniques based on multiple criteria such as project cost variation, the environmental impact, the impact on schedule and construction productivity. On the other hand, Attallah et al. [15] developed a MCDM methodology for ranking GB certification credits using ELECTRE III method. The selection criteria include project type and location, client type, experience and familiarity of architect/engineer.

Although Turkey is ranked ninth for LEED GB certification in the international arena [29], and many studies in sustainability was conducted ın Turkey [30–35], currently there is no study in Turkey that developed MADM tool for selecting the appropriate GB certification credits for a particular project. The other GB certification systems that are used in Turkey's construction industry are BREEAM, Deutsche Gesellschaft für Nachhaltiges Bauen/German Sustainable Building Council (DGNB), Comprehensive Assessment System for Built Environment Efficiency, Excellence in Design for Greater Efficiencies (EDGE), CEDBIK-Konut. (Çevre Dostu Yeşil Binalar Derneği/Turkish Green Building Council-Residence).

Review of the previous studies showed that none of the previous studies considered project team attributes [5,7,9,11,12,14], except one study [15]. In this study, Attallah et al. included a project team attribute, which is experience and familiarity of architect/engineer. However, other project team based attributes were excluded such as, “education and knowledge (i.e. accreditation on GB Rating System(s))”, “involvement of project teams into the GB project delivery process”. Besides, that study did not consider “integrated project team approach” which was strongly suggested as one the most considerable instruments for successful completion of a GB project [5,7,36].

When MADM analysis methods are investigated in the literature, it is identified that TOPSIS is strongly suggested for solving complex real life problems having numerous alternatives [37,38]. For this reason, it is actively employed in many disciplines such as design, engineering and manufacturing systems, supply chain management, health, safety and environment management, energy management and construction management [11,38,39]. TOPSIS is capable of detecting the best alternative(s) among numerous alternatives. However, if selection criteria (e.g., attributes) have varying relative weights for each alternative, it is suggested to combine TOPSIS with the Multi Attribute Utility Technique (MAUT) [40]. By using MAUT an overall utility value can be assigned to each alternative and rival alternatives (i.e., credits) can be evaluated based upon the attributes' weights, which can vary for each alternative [25,40]. However, such a hybrid decision making tool employing MAUT and TOPSIS were not developed in the previous studies.

3. Research methodology

In this study, a novel hybrid approach, in which the TOPSIS was integrated with the MAUT), was used to represent varying relative weights (i.e., relative weights of the tertiary attributes) of GB project team attributes and to perform the MADM analysis. In addition, the Delphi method was used to collect data from the experts to determined relative weights based on expert opinion. The following steps were performed to develop the GB-CS tool (Fig. 1): (1) a three-tier hierarchical framework of the GB project team attributes was built [26]; (2) credits under the LEED BD + C rating system were integrated into the framework as alternatives, and relative weights of the attributes in the framework were determined by applying the integrated use of the Delphi method and the Top-down Direct Rating (TDR) method; and (3) the developed framework with relative weights was used to perform