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A knowledge-based expert system for assessing the performance level of green buildings

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ABSTRACT

Sustainability has become an important initiative discussed and undertaken, not only by private buildings, but also by public buildings which both dealing with residential, office, commercial as well as hospital. Sustainable building is the practice of designing, constructing, operating, maintaining, and removing buildings in ways that conserve natural resources and reduce pollution. Rating systems provide effective framework for assessing building environmental performance and they measure a building's sustainability by applying a set of criteria organized in different categories. A good Green Building Rating System (GBRS) should cover key indicators reflecting a building's characteristics and keep their performance in balance. This paper proposed a knowledge-based expert system as a tool to assess the performance level of a green building based on assessment factors of green building rating systems. Analytic Hierarchy Process (AHP) and fuzzy logic is adopted in order to develop the knowledge-based expert system. The data for this research collected from the experts in the field via pair-wise and Likert-based questionnaires. Using AHP, the most important parameters of rating systems according to their weights selected to be incorporated in the Fuzzy Inferences System (FIS) of fuzzy logic model. The fuzzy rules (knowledge) discovered from the collected data for FIS to assess the performance level of the green buildings from the Environmental, Social and Economical perspectives denoted as SE2. The outcome of this research is accordingly a performance assessment tool that analyzes the effect of factors in developing the sustainable building.

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1. Introduction

Sustainability initiatives are considerable in the erection of new buildings, in the operation and the renovation of existing buildings and nowadays it is apparent that it has important impact on the building industry. As one of key outputs of the construction industry, buildings largely reflect resources and waste impacts during its lifecycle. Construction activities in general known as resource intensive and the impacts reflected in consumption of natural resources and pollutions [34].

Generally, sustainability is the ability of a system to continue on an indefinite basis typically incorporating economic, social, and environmental issues. The concept emphasizes the integration of humans in nature and requires that human activity remain within bounds avoiding impact on ecological systems [36]. Achieving a low carbon economy through building usage is necessary as it is responsible for approximately 40% of CO_2 emissions in the UK and across the EU, therefore policies on tackling energy use through design and development is of priority [37].

The awareness and importance of maintaining sustainable developments within the planning and engineering sector has led many to look toward new and innovative ways to incorporate sustainability into their designs. The term "green" building defines environmentally friendly techniques and technologies used in the design and construction of the built environment [38]. The green building revolution is sweeping across not only the United States but also most of the world. This revolution is further fueled by

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the knowledge that the world has little time to respond to the growing dangers of climate change, especially global warming, and that buildings play a huge role in causing carbon dioxide emissions that drive global climate change [73]. Green building technology for responsiveness to sustainable development is not only for private buildings but also for public buildings which dealing with residential, office, commercial as well as hospital has become a flagship of sustainable development in this century. Its goal takes the responsibility for balancing long-term economic, environmental and social health [71,58].

Assessing the performance of green buildings is a critical task as the different rating systems emphasize different aspects of building performance and has been an eye-catching topic these days [61,29,13]. Due to the fact that Men strive to increased comfort and financial independence, the effects of economic, and the quality of life is being hampered. While at the same time are also negative health effects that must bear from the damage due to the rising number of environmental catastrophes as result causes climatic change is experienced [48]. Sustainable building design will become a more common practice once interior environment primarily the productivity gains believed to be associated with the provision of high quality interior environments [24]. For example, research on environmentally friendly design and management systems has being conduct over the life cycle of buildings [53,63]. Besides, there are various methods for assessing the performance of buildings. Many of these methods emphasize the impact of buildings on the global environment and individual health, focusing on energy use, indoor climate and other environmental issues [18].

MCDM or MCDA are well-known acronyms for multiple-criteria decision-making and multiple-criteria decision analysis. MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria [40]. It has been utilized to solve many real-world problems [35,64,60,28]. Zadeh [74] introduced the concept of fuzzy sets to enable analysts to deal with imprecise and subjective concepts and to deal with linguistic variables in various decision and evaluation applications. Fuzzy MCDM (FMCDM) problems [26,65,41,39,12,10], among which the ratings and the weights of criteria evaluated on imprecision, uncertainty, and vagueness are usually expressed by linguistic terms and then set into fuzzy numbers.

A research by Lu et al. [39] that integrated human actions and complex socio-economic themes into the process of New Product Development (NPD) in order to adapt its design to various competitive markets showed the effectiveness of Fuzzy Multi-Criteria Decision Making (FMCDM) in theme-based product evaluation. Their method combined MCDM with Group Decision Making (GDM) methods and proposed hierarchical operators to fuse the data obtained from both human evaluators and machines.

We also take the advantage of MCDM and fuzzy set theory and develop an assessment tool for green buildings performance. In our proposed method, Analytic Hierarchy Process (AHP) is used for group decision making and ranking the performance assessment criteria and fuzzy inference system is applied for final performance evaluation of green buildings. Hence, in comparison with research efforts found in the literature, our work has the following differences. In this research:

1. Using AHP, the performance assessment criteria for green buildings are ranked and weighted from the SE2 perspectives.
2. Using fuzzy set theory, a new knowledge-based expert system for assessing the performance level of green buildings from the Environmental, Social and Economical perspectives is proposed.

1.1. Benefits of green buildings

Implementation of green building practices is believed will possibly achieve the three benefits, which is SE2 benefits [70]. The environmental benefits include: Biodiversity and ecosystems enhancement; Air and water quality improvement; Waste streams reduction; Natural resources conservation and restoration; and Minimizing the global warming.

While secondly, the economic benefits contribute to reduction in operating and maintenance costs; Green product and services creation, expansion and markets shape; Occupant productivity improvement; Occupant absenteeism minimization; Life-cycle economic performance optimization; Building image improvement; and reduce the civil infrastructure costs.

On the other hand, social benefits give to reduction in operating and maintenance costs; Green product and services creation, expansion and markets shape; Occupant productivity improvement; Occupant absenteeism minimization; Life-cycle economic performance optimization; Building image improvement; and reduce the civil infrastructure costs.

In a green building, energy efficiency used to describe in fulfill several criteria which need to be achieve. This include the use of energy efficient equipment, suitability of materials for the climate conditions, the service and amenities provided must fulfill the building use and the building should consumed less energy than the similar buildings. Besides, another important aspect should be considered is the embodied energy in both building construction and demolition [47]. Many countries have introduced to reduce the building energy in order to improve the energy efficiency in the building sector.

Since sustainable development with Social, Environmental, and Economical (SE2) principles encouraged to response to the measurement of carbon footprints, many rating systems were and being developed in order to assess the "green-ness" of green buildings and many in the field are thinking about measuring the actual performance of them i.e. " the performance of buildings that we considered green." For instance, many countries have developed their own rating systems either by setting up their own parameters or by modifying from the rating tools developed in other countries. Green Building Rating Systems (GBRS) is one of such systems that measure a building's sustainability by applying a set of criteria organized in different categories [11]. In these GBRS, the criteria perform various functions in measuring responsiveness toward the sustainable development. GBRS can support the decision-making process and increase the efficiency of actions by simplifying, clarifying and making aggregated information available.

1.2. The problem and our contribution

Assessing the performance of green buildings in their post-occupancy stage is the most effective way to insure that a building obtained what degree of success in its design. As the green building approach should consider three main criteria are Social, Environmental, and Economical (SE2); hence, the assessment tool for measuring the performance necessarily to take these criteria into consideration [11].

Throughout the phases of building life span, environmentally friendly built environments should be associated with safety, security, wellbeing, convenience, reasonable cost and long-term adaptability. Satisfaction of these criteria achieves an optimal combination of SE2 values for buildings [14,15,32,66]. Social, economic, environmental and technological dimensions are all important in evaluating building performance [16]. A wide range of criteria have been developed in order to assess building

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