Optimization of Strategies and Models Review for Optimal Technologies - Based On Fuzzy Schemes for Green Architecture

Ghada Elshafei, Abdelazim Negm

Abstract**—**Recently, the green architecture become a significant way to a sustainable future. Green building designs involve finding the balance between comfortable homebuilding and sustainable environment. Moreover, the utilization of the new technologies such as artificial intelligence techniques are used to complement current practices in creating greener structures to keep the built environment more sustainable. The most common objectives in green buildings should be designed to minimize the overall impact of the built environment that effect on ecosystems in general and in particularly human health and natural environment. This will lead to protecting occupant health, improving employee productivity, reducing pollution and sustaining the environmental. In green building design, multiple parameters which may be interrelated, contradicting, vague and of qualitative/quantitative nature are broaden to use. This paper presents a comprehensive critical state- of- art- review of current practices based on fuzzy and its combination techniques. Also, presented how green architecture/building can be improved using the technologies that been used for analysis to seek optimal green solutions strategies and models to assist in making the best possible decision out of different alternatives.

Keywords**—**Green architecture/building, technologies, optimization, strategies, fuzzy techniques and models**.**

I. Introduction

FOR many years, buildings that offer comfortable, flexible and energy efficient living environment at a minimal cost has been the expectation of building owners and occupiers. To attain this aspiration, a variety of advanced building technologies have been developed in the past two decades, aiming to improve the building performance to satisfy a variety of human needs and environmental sustainability [1]. The theories, techniques, and implementations of the green building aspects are the most difficult areas in architectural design among others. Techniques are a part of the design process in architecture, landscape and urban planning. Architects are entrusted with the responsibility of planning of environmental from a single floor to a complete house; a multi storied building to a large urban space which could even be megacities [2]. Recently, the architectural design including sustainable and green environmental parameters is typically formulated as follow:

The green design of the environmental architectural is defined as finding of feasible solutions for a set of interrelated factors that not only meet design requirements and maximize design quality according to design preferences but also satisfies aesthetic and usability. These factors include a log list such as renewable energies [3]; eco-designs [4]; solar energy, [5]-[7]; eco-lighting [8]; compressed shopper waste (CSW) blocks [9]; safe waste disposal [10]; comfortable air-conditioning facilities [11]; natural ventilation designs [12], [13]; shading designs [14]; heating systems [15], [16]; utilizing green roofs [17]; building envelopes, [18]; and wall insulation for buildings and double-skin facades [19]-[21].

The potential use of Information Technologies (IT), and Artificial Intelligence (AI) algorithms supported the researches in the domain of spatial assessment, optimization of urban planning and environmental design of buildings and it is now considered a major area of research [22]. There are various technologies that used in the green architecture/ building optimization and assessment, including AI algorithms, Genetic Algorithms (GA), Analytic Hierarchy Process (AHP), Fuzzy Logic (FL), with the combinations of other techniques as Fuzzy-Delphi (DFuzzy), Artificial Neural Networks (ANN), Neural Network Fuzzy (NNF), and Genetic Artificial Neural Networks (GANN) within the scope of environment impact assessment and decision support. Consequently, this paper comes on line to make a valuable critical review of the most recent applications (2010-2015) of one of these techniques, namely, fuzzy and its combination schemes. It focuses on the current state-of-the-art in the application of fuzzy techniques in virtual environmental simulation and corroborates relevant knowledge gaps.

II. Fuzzy Logic (FL) Concept

Among the AI techniques, the fuzzy logic is *conceptually easy to understand*, *flexible*, *tolerant of imprecise data*, *Capable of modelling nonlinear functions of arbitrary complexity*, *capable of building on top of the experience of experts*, *capable of blending with conventional control techniques* and *based on natural language*. To implement a fuzzy system, three main steps are needed, namely, (*Fuzzification*, *Inference* and *Defuzzification)*. Interested reader in building fuzzy systems can consult e.g. [23].

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III. Summary of Review on Fuzzy Combination Approaches

Fig. 1 summarizes the basic statistics of the most recent 44 studies on fuzzy systems and their combinations with mathematical programming approaches and their application within the years 2010-2015. These papers integrated the Fuzzy with the mathematical programming techniques; 25% of the reviewed 44 papers integrated the fuzzy systems as a mathematical programming technique, where 20% use fuzzy combined with AHP as shown in Fig. 1 (a). Forty nine percent (49%) of papers focused on Environment applications, where 21% focused on energy as in Fig. 1 (b). From Fig. 1 (c) it can be known that the most objective for the fuzzy implementation is for energy use. Fuzzy techniques are built as a theoretical solution for some problems like optimization, but most countries that used these techniques are Taiwan (21%) and China (16%) as in Fig. 1 (d).

A. Fuzzy Approach

The Fuzzy system approach by [24] is used to get the optimal selection of maintenance materials as a system technique, while [25] used it for home comfort to optimize the environmental home parameters in USA. Hsueh [26], [27] used the fuzzy scheme to optimize house energy and green architecture in Taiwan. Furthermore, [28] developed a technique based on Fuzzy approach for Energy and Comfort Management in Malaysia, but [29] used it in green house for energy saving in Canada, while [30] made a system for Green Evaluation in China. Michael et al. [31] used it in green residence as a system for evaluation of the residential planning in Taiwan. Dou et al. [32] built a fuzzy-based DEMATEL and fuzzy clustering approach and applied it in China to identify the relative relationship and significance of various factors that negatively influence Chinese government green procurement at a municipal level. Lacagning et al. [33] studied a preliminary step to the creation of software that primary care doctors can use to make a diagnostic decision, when deciding whether patients with nasal symptoms need allergy testing or not as a health care from air pollution in Italy. Afful-Dadziea et al. [34] studied applying a fuzzy comprehensive evaluation method (FCEM) in evaluating the performance of individual member countries with regard to the Millennium Development Goals (MDGs) in environmental. The result showed how, in the absence of enough data, the FCEM can be used to evaluate performance of member countries involved in the environment MDG project.

B. Fuzzy-Delphi Approach

The Fuzzy-Delphi method has been used by [35], [36] in Taiwan to (a) set proper tools to evaluate effectiveness in industrial development and policy promotion that help enhancing overall execution efficiency and improve final results. (b) to develop a multi-criteria evaluation model for developmental effectiveness in the cultural and creative industries by combining the group decision-making technique from Delphi and (c) to keep up with the changing business environment as an indicator for saving energy and environmental protection. Hung et al. [37] induced a floor area ratio incentives land developer as well as enhance the efficiency of land use. A highly comprehensive sustainability assessment of Green Building Rating System is applied for floor area incentive levels considering the green building as a structure of low carbon city strategy for urban regeneration units. Hsueh et al. [38] developed a Delphi method and fuzzy logic theory to construct a quantized community energy saving multi-attribute effect evaluation model, in order to evaluate the processes of community energy saving promotional effects. Quantization was used as the criterion for reviewing the outcome of policy implementation, thus helping to achieve a low-carbon lifestyle of communities. Kuie et al. [39] began with performing factor screening with Fuzzy Delphi Method to calculate criteria weighting, and therefore constructed neighborhood unit evaluation model under the concept of sustainability.

C. Fuzzy-AHP Approach

Combined AHP with Fuzzy Comprehensive Judgment (FCJ) was used by [40] in China in order to evaluate whether a construction scheme satisfies low-carbon standards fast and simply. Moreover, [41] used a general survey aims to collect and identify the design criteria that affect the energy demand model and to evaluate the priorities of each criterion using the fuzzy and AHP method. Furthermore, [42] introduced a comprehensive method that integrates the Life-Cycle Assessment (LCA) and Environmental Management Accounting (EMA) concepts, FL and AHP, to measure the environmental and organizational performance of different designs. They proposed a screening model to help designers reduce their reliance on LCA and presented a case study to demonstrate that this approach provides a systematic method of evaluating alternative designs and identifying product design improvement options. Lan et al. [43] used a Fuzzy Analytic Hierarchy Process (FAHP) to analyze the relative weight and the ranking of significance from individual factor. The result appeared the top 5 crucial factors that influenced consumers purchasing green buildings in Taiwan which are the price of green building, the level of environmental awareness, green building material and internal structure, the level of green consumption and income in subsequence. The decision-making of the consumers would not be influenced by the green building label, the gender and the age, the environmental propaganda of government, the value of mainstream culture and economic conditions.

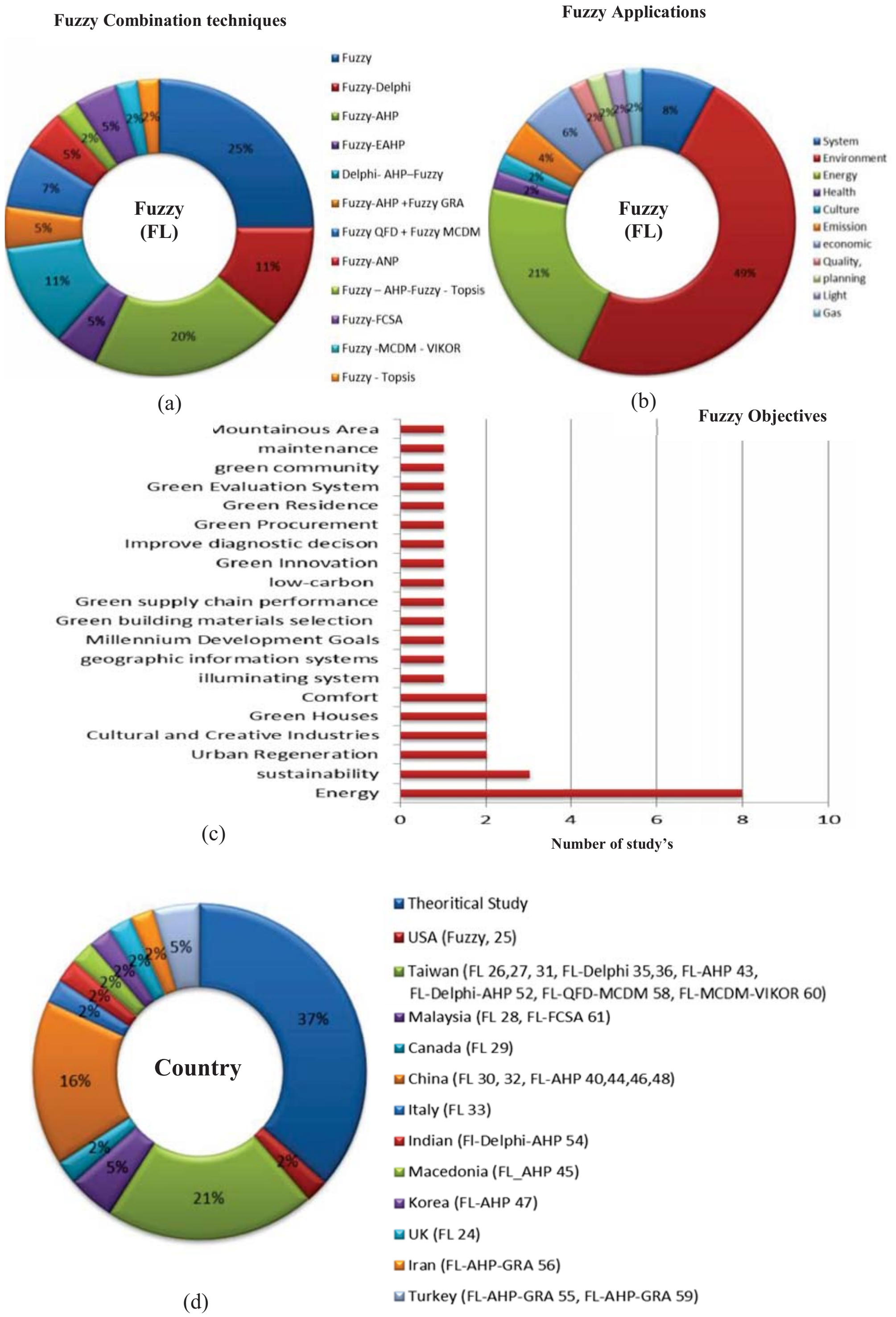

Fig. 1 Summary of the surveyed 44 recent (2010-2015) studies on Fuzzy technique and its combination with other optimization technologies/models in green building (a) the Fuzzy and its combination approaches, (b) Fuzzy Applications, and (c) Fuzzy objectives and (d) country-based used technology

In China, [44] developed a fuzzy-AHP comprehensive evaluation method (FACEM) to be suitable for the Coastal reclamation suitability evaluation (CRSE). They recommended applying the CRSE to other coastal areas in China for better management of coastal reclamation and coastline protection projects. In Macedonia, [45] combined fuzzy set theory with AHP and presented a geographic information system based multi-criteria site selection of non-hazardous regional landfill in Polog region. The systems were used for preliminary assessment of the most suitable landfill sites. The results proved that a least suitable landfill area of 1.0% from the total is generated when environmental and economic objectives are valued equally while a most suitable landfill area of 1.8% area is generated when the economic objective is valued higher. Yong et al. [46] studied the weighting value of the light evaluation when computed with the fuzzy analytic hierarchy process. Seong et al. [47] assessed the strategic energy technologies against high oil prices using five criteria including economic impact, commercial potential, inner capacity, technical spin-off, and development cost. They concluded that the relative efficiency score of energy technologies against high oil prices might be the fundamental decision making which help decision makers in Korea to effectively allocate the limited R&D resources. Tang et al. [48] built up a set of indicator system for evaluation of urbanization in mountainous area in Xianning (China's city) with AHP via conducting a fuzzy comprehensive evaluation of urbanization of mountainous area in Xianning.

D.Fuzzy-EAHP Approach

Current building materials selection methods fail to provide adequate solutions for two major issues: assessment based on sustainability principles, and the process of prioritizing and assigning weights to relevant assessment criteria. The FEAHP was used by [49] to prioritize and assign important weightings for the identified criteria to obtain a sustainable material selection which represents an important strategy in green building design. The model used an assessment criteria which were identified based on sustainable Triple Bottom Line (TBL) approach and the need of building stakeholders. A questionnaire survey of building experts is conducted to assess the relative importance of the criteria and aggregate them into six independent assessment factors. Also, Fuzzy-EAHP was used by [50] to determine the index weight of six different parameters, namely, environment, resources, energy, economic, technology and society to establish the green degree evaluation index system for four refrigerators.

E. Fuzzy-Delphi-AHP Approach

The integration of the fuzzy technique with AHP and Delphi method was found in 5 papers out of the 44 (11.36%). For example, [51] mainly applied Fuzzy-Delphi-AHP in building a quantitative evaluation model for sustainable community construction low-carbon development effectiveness. They used the model to (i) compare community low-carbon and energy saving development levels by calculating quantitative values as the basis for merits and (ii) evaluate the performance of low-carbon community construction projects. Furthermore, [52] combined three methods to develop a unique model for evaluating the energy-saving design of residential buildings in Taiwan. They showed that incorporating solar building materials, double-skin facades, and green roof designs can effectively provide high energy-saving building designs via applying (a) the Delphi group decision-making method to provide a co-design feature; (b) the AHP to include multi-criteria decision-making techniques and (c) fuzzy logic theory to simplify complex internal and external factors into easy-to-understand numbers or ratios that facilitate decisions. Moreover, [53] used the Delphi method, fuzzy logic, and AHP (DFAHP) as a risk assessment model to redevelop derelict public buildings. Alapure et al. [54] developed a unique model for assessing the sustainability of traditional built forms through using Delphi, AHP and Fuzzy logic theory for decision making verified using physical measurements via interview-based questionnaire in India.

F. Fuzzy-AHP-GRA Approach

The fuzzy-AHP-GRA combined approach can be applied to a complex decision process, which often makes sense with subjective data or vague information as used by [55]. They proposed a Buckley extension based- fuzzy Analytical Hierarchical Process (Fuzzy-AHP) and linear normalization based-fuzzy Grey Relational Analysis (Fuzzy-GRA) combined with Multi Criteria Decision Making (MCDM) methodology to solve Hydrogen Energy Storage (HES) selection problem in Iran with different defuzzification methods. Also, [56] investigated the potentiality of employing fuzzy-AHP along with fuzzy GRA for optimal selection of candidate tenderers in process with consideration of a hybrid fuzzy environment with incomplete weight information. The scheme was proposed and tested in Turkey to obtain the exact weight information, and aggregate different types of evaluation information so as to identify the optimal candidate tenderers.

G. Fuzzy-QFD-MCDM Approach

In fuzzy QFD, the operation is adopted to calculate the fuzzy set of each component. In prototype product selection, engineering characteristics and the factors involved in product development are considered. Three papers of 44 (6.81%) used a fuzzy-QFD and MCDM scheme. For example, [57] integrated fuzzy QFD and the prototype product selection model to develop a product design and selection (PDS) approach. A fuzzy multi-criteria decision making (MCDM) approach is proposed to select the best prototype product via a case study in Taiwan to provide product developers with more useful information and precise analysis results. Also, [58] examined a "fuzzy multi-criteria decision making" approach in order to analyze Building Energy Performance-Turkey (BEP-TR). This approach was applied to categorize alternative buildings according to their overall energy performance in a qualitative manner due to imprecise available data. On the other hand, the selection of the construction method for building projects involves a complex decision-making process. Therefore, [59] attempted to improve the environmental sustainability of green building projects by using different construction methods via the application of a MCDM approach in order to assess the priority construction method selection for each green building project and to aid construction companies with regard to their practical application.

H.Fuzzy-MCDM-VIKOR Approach

The fuzzy-MCDM and VIKOR scheme is an extension of intuitionistic fuzzy environment aiming to solve the green multi-criteria decision making (GMCDM) problem. It is used by [60] to develop a quantitative evaluation model to measure the uncertainty of Green Supply Chain Management (GSCM) activities and applies an approach based on Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method. Based on the performance of the considered companies in GSCM initiatives, the model results indicated that the main criteria of the research ranked as follows eco-design, green production, green purchasing, green recycling, green transportation and green warehousing.

I. Fuzzy-FCSA Approach

The Fuzzy – FCSA approach was used by [61] in Malaysia for resolving the conflict of maintaining the inhabitants comfort index and the energy consumption in buildings. The proposed Fuzzy Control System Architecture (FCSA) infers the graphical relationship between energy consumption and comfort parameters. With a distributed fuzzy inference system (FIS), control has been developed for temperature, air quality and artificial lighting comfort parameters.

IV. Conclusion

This paper presented a comprehensive state-of-art review for the current very recent AI-based-practices (2010-2015) using technologies, strategies, techniques and models that been used in green architecture/building for analysis to seek optimal green solutions strategies and models. The paper proved that an increasing trend of interest in optimization is maintained which is due to the fact that industries and builders are realizing the great potential of Fuzzy approaches such as Fuzzy-AHP, Fuzzy-ANP, because they are facing more stringent challenges than ever, with an increasing demand for designs to perform environmentally and economically.

It is observed that the fuzzy integrated methods are applicable and very effective and efficient in the field of green/sustainable building in a wide variety of research fields and environmental problems related to green architecture/ building. It was found that the fuzzy technique when combined with other approaches/techniques or models such as Delphi, AHP, EAHP, GRA, QFD, MCDM, ANP, TOPSIS and FCSA yields a more convenient approach for many practical qualitative and/or quantitative applications such as quantitative evaluation model for sustainable community construction and low-carbon development effectiveness. Based on the current survey, these recent technologies are widely used in developed countries such as USA, UK, Canada, Taiwan, China, Italy, Malaysia, Turkey, and Indian while in developing countries it still not widely used.

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