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Review

Opportunities for Using Analytical Hierarchy Process in Green Building Optimization

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Abstract: The adoption of green building technology has become significant for ensuring sustainable development; it has become the main step to a sustainable future. The designs for green buildings include finding a balance between comfortable home construction and a sustainable environment. Moreover, the application of emerging technology is also used to supplement existing methods in the development of greener buildings to preserve a sustainable built environment. The main problem of this research is how to tackle the environmental parameters balance based on new techniques that are being used for green building optimization. To mitigate the cumulative effect of the constructed climate on human wellbeing and the regular ecosystem, the most popular goals for green buildings should be planned. This can be achieved by efficient use of natural resources such as energy, water, and other resources and minimizing waste. This will contribute to the security of occupant health, enhancement of work performance, emissions control, and improvement of the environment. In the construction of green buildings, several criteria that may contradict, interrelated indistinct and of qualitative and/or quantitative environment are broadened to utilize. This paper provides a detailed state of the art analysis on improving existing practices in green architecture/building using analytical hierarchy process (AHP) techniques to tackle the environmental balancing values based on optimal strategies and designs by green solutions to help make the best possible option from numerous options.

Keywords: green architecture; green building; AHP method; optimization design; renewable energy

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1. Introduction

The buildings that propose a flexible, relaxed, and energy efficient nature for living at a low price has been the aspirations of residents of buildings. Several innovative design technologies have been introduced to accomplish this objective, to improve building efficiency, and to meet a range of human requirements and environmental sustainability [1]. Also, AHP's inherent capacity to cope with diverse styles of decisions, where it has been normally been applied in its development, has become its executive research aim throughout the last few years [2].

The implementations of green building problems, techniques, and theories are unique for the greatest challenges in structural planning. The techniques are a portion of the design method in urban planning, landscape, and building. Where the role of environmental design is assigned to architects from a single floor to a whole home, from a multi-storied structure to a large urban space that could even be found in a megacity [3]. The architectural design environmental problem is typically formulated as follows:

The green plan of the ecological architectural is defined as the finding of answers for many interrelated factors such as sustainable renewable sources [4], eco-designs [5], solar energy [6–8], lighting [9], compressed shopper waste (CSW) blocks [10], waste disposal [11], air-conditioning facilities [12], ventilation designs [13,14], shading designs [15], heating systems [16,17], green roofs [18], building envelopes [19], and double-skin facades and wall insulation for buildings [20–22], which not only comply with design specifications and optimize the efficiency of design according to design preferences but also satisfies usability and aesthetic requirements

Also, some state-of-art- references mentioned for the usability of the AHP scheme include the following: in construction management [23], select the certified parameters in the green building systems based on the AHP identification criteria [24], formulate an assessment model for environmental efficiency to identify the main performance matrix for the green building parameters [25], encapsulate the inclinations of properties among the main different keys to identify the life cycle performance of any structure [26], and gather the data from clients to investigate the main code of the structures so that they agree with the same requirements in the building plan [27].

Allocate a plan layer for the buildings as a main standard guide technique for the home components [28], utilizing a multi-mode dynamic technique to grantee the standard fulfillment of leaders and recipients for development measure for all of the building structure [29], empower the environmental friendly frameworks to create different green building rating systems to increase the quality of buildings [30], create a decision-making classical system to support investors in selecting the materials that wanted to yield sustainable buildings [31], and estimate a green score and rank hostels indicators that outline green training in industry to develop a model to measure the green score values for structures [32], developing a multi criteria decision study of factors to improve decision making in substructure building schemes [33].

To explore a development elements for sustainable built-up renewal building to assess the masses of the derivative elements of it [34], select a fruitful retrofitting strategy that imitates the decision maker's aims to aid accomplish the objective of zero-energy constructions [35], building a criteria to rank some of indicators based on their level of significance to solve the energy conservation glitches [36], estimating a multidimensional measures that reflects all views in the building manufacture procedure to generate a fit and error-free buildings [37], building an internet-based policy development for smart buildings to study the features of any progress stage in buildings design [38].

The potential use of artificial intelligence (AI) algorithms, technologies, and information in decision support systems is well understood in regeneration and urban planning. In any case, concerns have been raised while starting endeavors regarding recovery arranging inside the populated fabricated conditions causing an elevated degree of natural hardship and financial effects from the existing local area. With the advent of high-speed internet technologies, improved sophisticated AI techniques, and graphical automation, the domain of spatial assessment and optimization is now considered a major area of research [39].

This paper uses the presentation procedure of [40] to make a valuable review of various AHP technologies that are used in the green building optimization and valuation within the scope of environmental impact assessment and decision making. This paper will analyze the incorporation level of the impact for several socio-economic parameters, such as health, transport, accessibility, employment, sustainability, and smart growth within urban renewal systems. The exploration shows that keeping up with and controlling the adverse consequences of these elements altogether will generally limit the financial and ecological hardship in assembled climate areas.

Also, the paper evaluates the work conducted in regards to the area of urban planning and renewal in terms of information visualization and decision support tools. Previous research carried out in strategies and models for urban subsystems will also be discussed.

The discussion will finally conclude the current state-of-the-art in the applications of environmental modeling, the use of numerous AHP, and evolutionary computing methods that corroborate relevant knowledge gaps. Ultimately, the paper will present some comparisons to get the development of an optimization solution based on the assessment of various socio-economic deprivation factors. This paper aims to provide a better overview of the areas of decisions and the problems of decisions that AHP might work effectively.

The paper is organized as follows. Section 1 contains the introduction, Section 2 demonstrates the main hypotheses and purposes of the work, Section 3 presents the scope and specifications, and Section 4 explains the AHP algorithm as an optimum search-technique. In Section 5 we present the AHP issues and approaches that have been combined in green architectural optimization techniques. In Section 6, the concluding section, we highlight issues that can be addressed by our work along with some final findings and a summary of the study.

2. Methodology

Green building for structures and even urban areas has become an inevitable theme for designers, organizers, engineers, and different investors. The purpose of this analysis is to carry out a comprehensive and quantitative examination of green building engineering approaches and developments in the initial stage with an emphasis on evaluating and assessing the innovations from the viewpoint of construction decision-taking AI focused on the AHP technique.

The motives for this study are as follows. Architectural construction is an extensive practice mixing specific interests with objective thinking. Compared to conventional graphic design, architects face a question about how to manage the data-based design process. Second, architects' technical skills are more rigorous than in any previous time, in which subtle trade-offs in architectural designs and functional logic may have occurred. Finally, the nature of the construction environment needs various engineering team members to operate together in the process, which is radically distinct from the previous style of operation. Architecture and green buildings are offering more compelling reasons for urban design actions to planners and architecture experts.

The hypotheses related to environmental architecture are that the method in which green construction used maybe translated (directly or indirectly) into the recognizable elements of architectural types and their specific forms. In other terms, various strategies are introduced in the optimization phase. In summary, this analysis aims to compile and examine appropriate research and address the real benefits and possible problems in the sustainability sense of performance-oriented building design and optimization.

3. Scope and Specifications

Science Direct and Web of Science were used to accomplish a worldwide quest for articles and conference papers that relevant to this research. The keywords included "urban design", "technologies", "optimization", "analytical hierarchy process", and "techniques and models". Diverse variations of the keywords listed have been produced. The date chosen for all works published was from 2000 to 2022. Even so, the number of accessed publications was still massive.

This analysis intends specifically to demonstrate the green building benefits provided by the construction or optimization scheme. Under this requirement, the analysis material must include recognizable graphic elements or style attributes to give it specific architectural design language.

Also, the main study topics include energy, environment, and manufacturing, which follow expectations as they often lead to sustainable development. Green building design dependent on construction specifics is undeniably a dynamic and definitive work field. The key focus here is the green building strategies that planned to reduce the total effect of urban infrastructure on human wellbeing and the natural environment. This can be carried out by utilizing natural resources including water, energy, and other resources efficiently, and by reducing waste.

The findings indicate the vulnerability of the numerous properties and variables based on the particular design objectives. The most commonly employed optimization methods and previously listed simulation techniques are not unintentional. Other traditional features allow it to stand out in the area of functional application. Firstly, this method has been described as an architect friendly for architects and decision-making engineers. Second, the system transmits data from various job channels, so criteria for input and output may be evaluated and reviewed easily. Finally, the technique embraces several alternate models being contrasted [41].

4. AHP Scheme

The AHP is a decision-making approach with several parameters that were introduced by Saaty [42]. The AHP has drawn the attention of many researchers due to its mathematical properties and the method of obtaining the necessary input data that followed. The AHP is a decision-making method that can be used to address difficult issues with decisions. It utilizes a hierarchical system of requirements, sub-criteria, priorities, and alternatives at various stages [43].

The primary operations of the AHP include hierarchy building, priority analysis, and testing of continuity. Next, decision-makers need to break down specific judgment problems with various parameters into their parts with potential characteristics arranged at various hierarchical stages. After that, based on their expertise and knowledge, the decision-makers have to compare each cluster at the same stage in a pair-wise manner. For instance, in the second level, every two parameters are compared with the target at any stage, while in the third level, every two attributes of the same parameters are compared with the corresponding criterion. Since the similarities are made by personal or decisions, there may be a degree of inconsistency.

The final procedure is called consistency verification, which is considered to be one of the most benefits of the AHP, where it is implemented to ensure that the conclusions are consistent. Then, to calculate the degree of consistency among the pairwise comparisons that can measure the consistency ratio. If the accuracy ratio is found to exceed the limit, the pairwise comparisons should be checked and updated by decision-makers. After all, pairwise analyses are carried out and shown to be accurate at all stages, the decisions can then be synthesized to figure out the priority rating of each parameter and its characteristics. AHP's procedure is shown in Figure 1.

Among many journal/conference articles, 84 papers integrated the AHP with the mathematical programming techniques, including mixed-integer linear programming (MILP), integer linear programming (ILP), and goal programming (GP). The AHP combination and the applications of the mathematical programming approaches are summarized in Table 1.

Table 1. Summary of all AHPs for sustainability and building design optimization schemes 2000–2021.

Scheme	Objective	Applications	Authors	Date	Country
AHP	indoor and outdoor environment	Environment	Bing et al.	2010	China
	Green Buildings	Environment	Ali et al.	2012	Malaysia
	characteristics of 'viable' methods	Methods	Arroyo et al.	2012	Theoretical
	energy saving	Energy	Yang and Suo	2014	China
	apartment building	Environment, Energy	Choi et al.	2014	China
	site of urban parks	Environment	Elahe et al.	2014	Iran
	aspects of green technology	Energy, Water	Jawdat et al.	2014	Amman
	green stores	Energy	Wei et al.	2015	China
	industrial building direction	Environment	Wang	2014	China
	Construction Management	Construction Management	Amos et al.	2004–2014	Theoretical
	Sustainability and Costs	Environment	Ryan et al.	2017	Florida
	Sustainability assessment	Refurbishment	Syahrul et al.	2018	Malaysia
	Green building & sustainability studies	Environment	Fatma et al.	2019	Turkey
	Habitability Performance and Sustainability	Environment	Hyang et al.	2019	Korea
	Sustainability and Costs	Environmental efficiency	Ryan et al.	2020	Florida
	life-cycle performance	Design assessment	Al-Saggaf et al.	2020	Theoretical
	sustainable assessment	Energy and resourses	Payyanapott and Thomas	2020	India
	assessment plan components	structural plan practice	Xingkai	2021	China
	building quality	assessment framework	Eryürük et al.	2021	Theoretical
	building rating frameworks	green building	Chodnekar et al.	2021	India

Table 1. *Cont.*

Scheme	Objective	Applications	Authors	Date	Country
	Selecting building materials	Construction	Abdulhafeez	2022	Saudi Arabia
	Decision making	Infrastructure construction	Solomon et al.	2022	Ethiopian
	planning elements determenation	Sustainable urban regeneration	Jihad et al.	2022	Dubai
	Zero-energy buildings	Building Retrofitting	Sobhi	2022	Saudi Arabia
	Energy	sustainability	Yadegaridehkordi et al.	2022	Malaysia
	Stakeholder satisfaction	Building design quality	Şule et al.	2022	Theoritical
AHP–ILP	Material selection	Manufacturing	Braglia et al.	2001	Theoretical
	Sub-component selection	Manufacturing	Akgunduz et al.	2002	Theoretical
AHP–MILP	Transportation route selection	Logistics	Korpela et al.	2002	China
	Airlift task selection	Government	Stannard and Zahir	2006	Canada
	Scheduling selection	Logistics	Zhou et al.	2000	China
AHP–GP	Customer data method selection	Service	Badri	2001	Emirate
	IT-based project selection	Health-care	Kwak and Lee.	2002	Korea
	Trust factor selection	Industry	Radclive and Schniederjans	2003	USA
AHP–QFD	Facility location selection	Logistics	Chuang.	2001	Theoretical
	Product design selection	Manufacturing	Kwong and Bai	2003	Theoretical
	Facility location selection	Logistics	Partovi	2006	Theoretical
	Rapid process selection	Manufacturing	Hanumaiah et al.	2006	Theoretical
AHP–ANN	building design	Inhabitant thermal	Varolgüne et al.	2021	Turkey
	Convenience location selection	Logistics	Kuo et al.	2002	Taiwan
	Job schedule selection	Manufacturing	Chang and Lo.	2001	Theoretical
AHP–GA	route selection	Logistics	Chan and Chung.	2004	Theoretical
	route selection	Logistics	Chan and Chung.	2004	China
	route selection	Logistics	Chan et al.	2004	China
	route selection	Logistics	Chan et al.	2005	China
	route selection	Logistics	Chan and Chung.	2005	Theoretical
	route selection	Logistics	Chan et al.	2006	Theoretical
AHP–SWOT	Energy assessment	Energy	Fahem et al.	2017	Algerian
	evaluation in forest planning	Environment	Kurttila et al.	2000	Finland
	assessment in rural tourism planning	Tourism	Kajanus et al.	2004	Finland, Germany
	evaluation adoption	Agriculture	Shrestha et al.	2004	USA
	evaluation planning	Environment	Masozera et al.	2006	Rwanda
	evaluation analysis	Manufacturing	Shinno et al.	2006	Japan
AHP–DEA	Government location selection	Government	Takamura and Tone.	2003	Japan
	Facility layout selection	Manufacturing	Yang and Kuo.	2003	Taiwan
	Performance evaluation	Government	Saen et al.	2005	Iran
	Facility layout selection	Manufacturing	Ertay et al.	2006	Theoretical
AHP–ANP	Building Energy Efficiency	Environment	Pengpeng.	2013	China
	built environment	Environment	Joseph et al.	2012	Theoretical
AHP–GIS	Green Store Buildings	Landscape	Wei	2015	China
AHP-LCSA	mid-rise buildings	Environment	Navid et al.	2014	Canada
AHP-Fuzzy	low-carbon Constructions	Emission	Ling et al.	2013	China
	Energy Demand in New Building	Energy	Hai et al.	2013	Theoretical
	Green design: env. Management	Environment	Chan et al.	2014	China
	Green Buildings Application	Environment	Lan et al.	2014	Taiwan
	Assessing coastal sustainability	Environment, Socio-eco	Fen et al.	2014	China
	GIS	Environment, economic	Katerina et al.	2015	Macedonia
	illuminating system	Light	Yong et al.	2015	China
	energy R&D resources	Energy	Seong et al.	2015	Korea
	Mountainous Area	Economic	Tang et al.	2015	China
EAHP-Fuzzy	Academic building	Energy	Ardisa et al.	2020	Indonesia
	green building	building location	Li et al.	2020	China
	green building	Environment, Energy	Yan et al.	2021	China
	Sustainable materials	Environment	Peter	2013	Theoretical
	Energy Saving	Energy	Jian	2014	China
	Sustainable development	Energy	Sung et al.	2011	Taiwan
AHP-Fuzzy–Delphi	Energy design	Environment, Energy	Kuang et al.	2012	Taiwan
	public buildings	Environment	Sung	2013	Theoretical
	Sustainability assessment	Environment	Alapure et al.	2014	India
	gas power plant	Gas	Saffarian	2015	Turkey
AHP-Fuzzy-GRA	Energy storage selection	Environment, Energy	Alev et al.	2013	Theoretical
AHP-Fuzzy-IRP	Risk factors of green supply chain	Manufacturing	Sachin et al.	2015	China
AHP–TOPSIS	Smart construction	Internet platforms	Kang et al.	2022	Theoritical
Fuzzy AHP-TOPSIS	Green score measurement	Hospitality Industry	Sujan et al.	2022	Oman

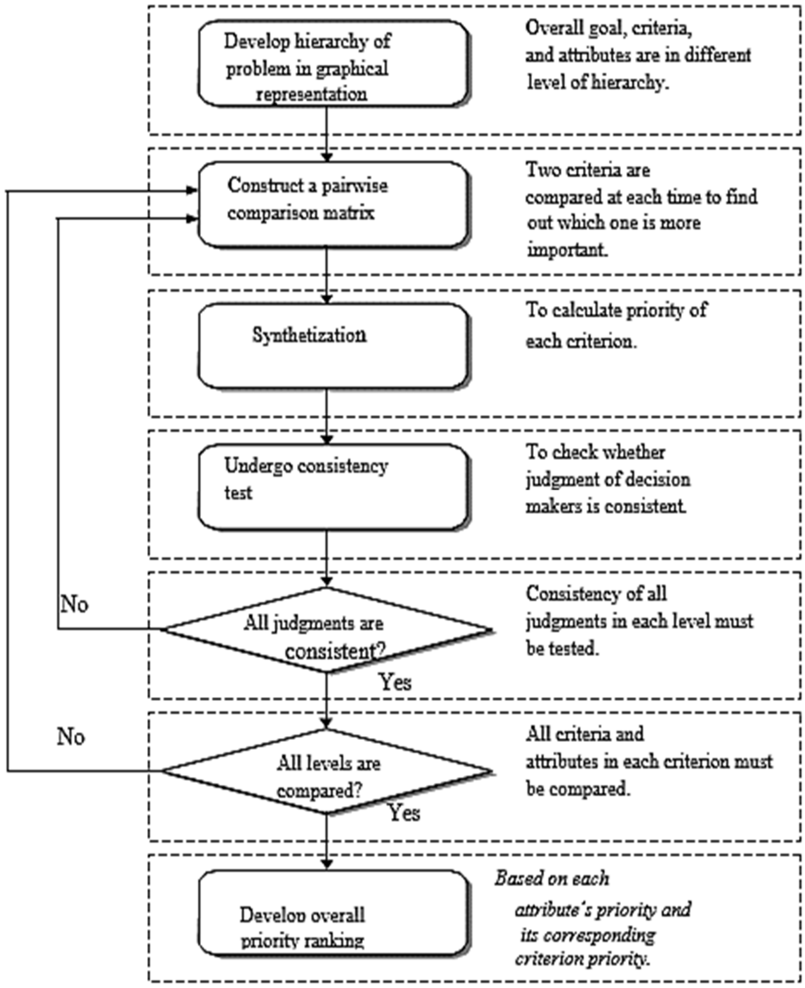


Figure 1. The analytic hierarchy process flowchart.

5. AHP Combination Approaches

An initial search for relevant works was conducted using Google, Library Genesis scientific papers, Egyptian Universities Library (EUL), with search terms including 'sustainable', 'energy', 'green', 'architecture', 'building', and 'optimization'. Further searches were then conducted in the archives of the journals and conference proceedings, (conference papers are included unless a similar journal paper exists, in which case it is given in preference). The papers that were cited by this work were also checked for relevance. Papers were chosen from this large search for inclusion in the main overview of Table 1.

The search included all of the areas of sustainable building design; it was exclusively concerned with energy and carbon emissions. For technologies used in buildings, works with significant information as the specification of an air conditioning system is included for a building. Some works made significant use of computational optimization, and some others used the term optimization, but they perform only algebraic or manual processes as a computation (e.g., identifying the minimum). In the following, the AHP issues with other techniques are identified.

5.1. AHP Approach

Bing Wei et al. [44] discussed the configuration and the specialization necessities for layouts of green structures. The evaluation principles, model, and strategy that are suitable for the circumstances in China are situated up by joining the attributes of open-air, indoor environmental of green structures, appraisal list, and arrangement of ecological quality. The processes of the evaluation models of the analytic hierarchy process are established. Ali Zarch et al. [45] accomplished the variables that contributed to the growth of green Malaysian residents through the systematic various levels of methodologies. The researchers uncovered that the components, as diminishment of contamination and well-being of health more needed among Malaysian natives and during the extension of green buildings in Malaysia. Also, the buildings that focus on healthy and indoor environmental quality are getting interests among Malaysians. P. Arroyo et al. [46] concentrated on the fundamentals attributes of suitable techniques that can be applied in some applications and correspondingly, the other attributes that exclude strategies in other applications. So, they choose the variables based on the trademarks that appeared to us for practicality, where theses variables are not to be weighted.

Yang Yong and Suo Chenxia [47] manufactured a three-level list for arranging occupants' fulfillment assessment in Beijing. The provincial inhabitations were identified through exploration and field study of building vitality, and every record in the inhabitant's gratification fulfillment list framework was gotten by utilization of the AHP entropy technique, and they analyzed those records to get a plan of buildings design, that accomplished the inhabitants' gratification. Choi et al. [48] conducted a review that focused on the occupants of a flat building that was guaranteed as green building architecture and looked at the significance of the evaluation criteria on condo structures to ensure green structures by utilizing the AHP strategy. Moreover, they proposed a new direction on certification assessment standards from the resident's perspective. Thus, appraisal criteria, for example, indoor environment, natural environment, energy, environmental contamination, and upkeep administration are among seven principles that turned out critical on evaluating the green standard for energy and environmental design (G-SEED) framework for flat structures. While criteria, for example, water flow administration, material and asset, transportation, and area use were moderately insignificant.

Tahmasebi et al. [49] studied the optimal site selection of urban parks at a local level in the city of Shahrood, which integrated the GIS system with overlaying. In the first place, criteria were fused into GIS and new data layers were made, that were utilized in conjunction with the current information to get data, for example, military areas, modern industries areas, and besides a desert status. The determinant criteria were weighted in AHP, and pairwise examination was directed to find the ideal different option for building a nearby scale park. Jawdat Goussous and Abbas Al-Refaie [50] assessed the execution of green innovation in current building design, flow building plan and provide acceptable decisions using life cycle cost (LCC) and investigation cost order process systems; the two essential parts of green innovation are considered: energy and water. Wei Yu et al. [51] added a reasonable rating strategy for green stores, this technique referenced the rating prerequisites set by the "China Green Building Evaluation Standard" and weighted credits for all classes. This technique was kept away from the impact of "imbalanced execution" when marking green structures, where the expert decision AHP strategy was used to add the weighting framework for green store structures. The weight circulations highlight the significance of indoor natural quality, operation, administration, and energy effectiveness inside the store buildings, also in industrial buildings [52].

Wang Hui-Jing [53] depicted the assessment substance and extent of the industrial green building, reflects off the modern green building course and the arrangement of imperative quantifiable parameters. Also, the paper presented the compiling process of the green industrial building evaluation standard, through the group experts of the AHP method. They discussed the rationality of the weight allocation result, through analysis and comparison of the assessment of the index system for the green industrial building as the British BREEAM industrial building and the domestic green building.

Ryan Doczy et al. [54] proposed a model using two projects to refine the choice of an alternative design given the competing priorities of the project: cost, leadership in energy and environmental design (LEED), and net-zero. The proposed model incorporates both the AHP and multiple attribute utility theory (MAUT) in a way that a decision-maker can determine the priorities of a project and use weights to assign those objectives. The findings revealed the validity of the model and its relation to sustainable development design practice.

Amos Darko et al. [23] reviewed about 77 AHP-based papers from 2004 to 2014 to help identify and delineate the AHP task areas and problem-solving decision-making within construction management. The results showed that the most common implementation fields of AHP in construction management were risk management and sustainable design. AHP has also been discovered to be versatile and as a stand-alone tool or in conjunction with other approaches, it may be used to address building decision-making problems where it is commonly used in Asia.

Syahrul et al. [55] aimed to support the creation of Malaysia of a refurbishment sustainability appraisal scheme. The AHP technique has been adopted to rate evaluation topics and classify the preferences of participating stakeholders in the research. A collection of weightings and a grading system for the preferred test themes and sub-themes are used in the result. To achieve the aims of sustainable growth by refurbishment, the techniques and results can be tailored for the use of other professionals to create building appraisal schemes. Results showed that the energy and efficiency of the indoor environment quality are the most effective analysis topics for stakeholders participating in the AHP with coefficients weight of 0.208 and 0.182, respectively. Therefore, higher credits are distributed in the MRAS for the electricity and indoor environment quality. These results were assisted during confirmation by interview experts since these two themes of evaluation are the key themes important for the built environment in Malaysia. Established buildings in Malaysia are occupied by old and aged buildings that are low in resources and have poor ventilation.

Harputlugil, et al. [56] conducted a study to select a green building certification System for Turkey based on identifying the most relevant requirements and criteria to be included in establishing a green building certification system in Turkey. They developed a questionnaire based on the AHP technique by determining criteria and sub-criteria, where it analyzed with software. The findings of the study revealed that; all of the current certification systems do not suit perfectly for Turkey, so it is concluded that the implementation of a new national certification system is needed.

Lee, et al. [57] studied how to enhance Korea's overall residential efficiency by developing the principle of its habitability functions that is distinct from contemporary architecture and providing a performance appraisal model focused on inherent characteristic evaluation factors. Thus, they tried to build an evaluation system composed of proven evaluation items or factors and carried out AHP analyses with certified experts, and applied the relative importance among the evaluation items. Finally, this study suggested an estimation model of the efficiency of habitability. The proposed evaluation framework was applied as the inherent value and its objectivity to be a sustainable method of regeneration for contemporary residency in Korea as a result of applying the evaluation model for weighted habitability results.

Emre Ilicali [25] focused on the level of sustainable project success and environmental performance. This research aims to provide a source for these issues and to assess the environmental success of urban redevelopment projects systemically. It also includes the formulation of the model for assessing environmental efficiency and identifies the main performance metrics. The AHP model being proposed integrates nine efficiency parameters and 55 associated KPIs. They are classified using a 7-point Likert scale questionnaire to assess their priority after assessing the hierarchical structure of KPIs. Then, via the involvement of 25 experts, the AHP process was carried out. Finally, the model for assessing environmental efficiency in urban redevelopment projects was created. The results of the analysis suggest that "energy" requirements have the highest degree of importance in assessing the environmental efficiency of urban regeneration projects. As a consequence, requirements for "water" followed by "land use" and "ecology."

Al-Saggaf, et al. [26] attempted to diminish the subjectivity in the design assessment. They utilized the AHP to foster a decision support system (DSS) to encapsulate the overall inclinations of the proprietor and planner among different key standards (implementations, cost, beauty, and so on) to identify the life-cycle performance of the structures. A contextual analysis with five elective designs is similarly liked by specialists, is utilized to show the DSS capacity to rank the plans as far as generally speaking performance scores. The AHP scheme upholds the complicated assessment measure that describes fundamentally each model, in turn, to show up the best plan, considering all standards of the time.

Payyanapotta and Thomas [27] presented an information-driven and easy-to-understand structure that cross analyzes the green structure rating frameworks and energy preservation codes dominating India. This system used the data gathered from the client to create code-agreeable structure plan techniques by utilizing the AHP. It considers that the structure's present maintainability level and joining the client's inclinations in working on the general manageability of the structures. The proposed building has encouraged clients to test the proficiency of different supportable developments and advance more practical construction in the country.

Xingkai Gu [28] summed up some of principles and techniques for an assessment of the plan components of Jiangnan's traditional home buildings. According to this basis, He built a plan component list arrangement of structures, which incorporates 4 measures layers and 16 plan layers. As per the AHP cycle, the weight of each plan layer is allocated, and a total record arrangement of home plan components is built to guide and reference the future structural plan practice and the standard style molding of the Jiangnan region. He can choose elements later in his plan to acquire and enhance formal building engineering.

Eryürük et al. [29] utilized a multi-mode dynamic technique to guarantee the alternative gratification between the leaders of decisions and recipients in the development of measures that are dependent on the AHP. Four fundamental sub-models were controlled by adding "green and manageability issues" to the "usefulness", "quality of building", and "effect" set of three for the improvement of building quality. The strategy utilized depends on an assessment framework that thinks about every one of the partners' demeanors. Important information is accumulated from three sorts of partners; a specialized group, a group of residents, and the last one is the group of construction firms as offices supervisor. It has been inferred that the meaning of standards and records of weights for all of them will not be controlled by just a single partner in a venture, additionally, all specific partners are likewise will be incorporated during arranging and application measure.

Chodnekar et al. [30] utilized the AHP strategy to empower the most part of the nations on the planet to create and explore different green building rating frameworks. These frameworks incorporate rules such as energy productivity, detached plan angles, environmentally friendly power frameworks, life cycle appraisal, post-inhabitance assessment, site arranging, and assets protection perspectives and developments which are normal in the greater part of the nations' evaluating frameworks of these green standards. They intended to examine the voids between the theories if green rating frameworks and the reception of the green details practically speaking in development projects that will assist with calling attention to the obstacles in the reception and execution of green structure strategy that is being better utilized.

5.2. AHP-ILP

Braglia et al. [58] utilized the AHP to focus on the relative significance weightings of the option took care of material devices. The assessment criteria were advantageous, expensive, and similar to every device regarding assembling cells. The weightings were then consolidated into the Integer Linear Programming (ILP) model. The goal was to choose a situated of tools with the most extreme weighting. Akgunduz et al. [59] developed an ILP model to find the best mix of choices for parts and sub-segments, with the destinations of expanding consumer loyalty and minimizing the item cost.

5.3. AHP-MILP

Korpela et al. [60] utilized the consolidated AHP and multi-target Mixed Integer Linear Programming (MILP) way to deal with managing the general logistics circulation issue. It was to focus on many issues as: (i) which third part stockroom administrators are deciding to serve the clients; (ii) what are the numbers of items that circulated. In their methodology, the AHP was utilized to quantify the relative significance weightings of options administrators in light of three criteria: flexibility, unwavering quality, and costs. Then, the AHP weightings are used as weighting variables as a part of the target capacity of the MILP model, through/the goal of amplifying clients' fulfillment. Stannard, B. et al. [61] joined AHP with MILP to ascertain the ideal portion of a predetermined number of airplanes among a collection of carrier clients with differing levels of length and need of use. Canadian Forces airdrop organizers commonly used this experience such a scope of organizing issues. These issues oblige the compelled task of variable-length missions (undertakings) coordinating many airdrops demands from a few clients with numerous needs to airframes (parallel machines).

5.4. AHP-GP

Zhou, et al. [62] proposed a goal programming (GP) model to address the multi-target issue with the combination of non-relaxation imperatives and relaxation confinements. The AHP, a multi-target choice-making system, is utilized to assess the needs of objectives and weights of deviation variables; its application is shown by a contextual investigation on supportable inventory network improvement of a petrochemical complex and planning. Badri [63] proposed a choice that will permit weighting (organizing) of an association's extraordinary administration quality measures, considered the genuine of impediment world asset (i.e., spending plan, hour, work, and so on.), and selected the ideal arrangement of administration quality control instruments. The paper addressed two essential issues: how to join and choose quality control measures in an administration industry, and how to consolidate the AHP into the model. A true contextual analysis represented the use of this joined AHP–GP mode.

Kwak and Leeb [64] studied the use of the multi-criteria mathematical programming (MCMP) as a manual for vital getting ready for business process framework improvement in an association with GP. The objective levels are recognized and organized utilizing the AHP. The outcomes are investigated, and the came about arrangement suggestion is assessed to enhance the model materialness. Radcliffe, L.L. and Schniederjans, M.J. [65] presented application consequences of utilizing two systematic techniques that were used to evaluate the overview data from the Spallation Neutron Source (SNS), USA's biggest science venture. The two choices systems created results that helped bolster the SNS administration's judgment that particularly chosen trust classes ought to be underscored to fabricate trust in this undertaking by using the AHP-GP strategy.

5.5. AHP-QFD

Chuang, P.T. [66] combined AHP and quality function deployment (QFD) strategies to reinforce an office territory decision from a need perspective. The methodology started by recognizing area prerequisites, then deduction of area assessing criteria, at long last a focal relationship lattice was built up to show the level of relationship between each pair of area prerequisites and area foundation for the QFD process. Kwong, C.K. et al. [67] enhanced the loose positioning of client necessities acquired from studies in light of the customary AHP. Moreover, the AHP with degree investigation was straightforward and simple to actualize and organize client needs in the QFD procedure contrasted and the ordinary of AHP.

Partovi, F.Y. [68] presented a key answer for the office area issue which joins both outside and inside criteria in the choice making procedure. The outside parts of the model were clients and their needs, rivals, and the attributes of different areas, where the inside components of the model were the discriminating procedures in the assembling association. The structure displayed the uses of QFD and AHP, but the model calibrated and added accuracy to the generally subjective vital choice procedure. The relevance of their proposed model was exhibited by a contextual investigation that condensed a mediation in which the model's system and fundamental ideas were applied. Hanumaiah, N. et al. [69] presented a QFD-AHP philosophy which has three stages. The main stage includes organizing the tooling prerequisites (driven by client inclinations) against an arrangement of die/mold improvement properties (for example, item geometry, material, die material, and creation request) through pairwise examination utilizing the expository hierarchal procedure. These need appraisals that are utilized for selecting the most fitting apparatus procedure by using QFD in the second stage. At long last, QFD is utilized again for distinguishing basic procedure parameters (for example, layer thickness, sweep pitch, and laser force) for the choice of the real-time (RT) process.

Kürüm Varolgüne et al. [70] explored a planning model to further develop the plan quality in building structures, specifically in a building of a thermal inn lodging. The strategy depends on applying the quality function deployment (QFD) procedure to pay attention to the client, notwithstanding the analytic hierarchy process (AHP), which permits the determination of the best plan elective. The results show that QFD–AHP techniques have been attempted in various spaces of the structure business. As per the discoveries, QFD was demonstrated to be an appropriate strategy for moving client (inhabitant) necessities to plans in the most precise way, given the perplexing design of thermal hotel buildings structures.

5.6. AHP-ANN

Kuo et al. [71] built up a choice emotionally supportive network for finding another suitability accommodation store. The proposed framework comprised of four parts: (1) various leveled structure advancement for fuzzy AHP, (2) weights determination, (3) information accumulation, and (4) choice making. Artificial neural network (ANN) feedforward with error back propagation (EBP) learning calculation is connected to discover the relationship between the elements and the store execution. The outcomes demonstrated that the proposed framework can give more exact results than relapse model incorrectness.

5.7. AHP-GA

Chang and Yu [72] proposed a coordinated methodology for demonstrating the employment shop planning issues, alongside a genetic algorithms (GA)/Tabu Search (TS) blend arrangement approach. Besides, sensible issues, for example, the instability angle, rescheduling, the relative significance of criteria, and option procedure that arranged with the GA/TS methodology, are additionally displayed inside of the system of the multi-target capacities.

Chan and Chung [73] built up a multi-paradigm genetic algorithm for enhancement and taking care of supply chain issues in-store network administration. Some appropriation issues managed conveyance from a few sources to a few destinations, in which Different elements of preference are interrelated and influence each other. GA plans have been generally received as the advancement instrument in taking care of these issues. They joined AHP with GA to catch the multi-paradigm choice making. The proposed calculation permitted leaders to give weightings for criteria utilizing a pairwise correlation approach.

Chan and Chung [74] built up a multi-measure genetic algorithm advancement methodology that intended for taking care of streamlining issues in-store network administration. The proposed calculation is examined with a request conveyance issue in an interest-driven store network system that consolidated the AHP with the GA scheme. Some numerical results that got from the proposed calculation are contrasted and the multi-target blended in a whole programming methodology, where the examination data demonstrated that the proposed calculation was solid and vigorous.

Chan et al. [75] contemplated vertical and level inventory network coordinated effort and proposed an interest sharing approach in light of an arrangement of predefined joint effort rules. The advancement procedure joined an AHP with GA. They produced a hybrid GA For manufacturing and logistics concerns in multi-factory supply chain models. The supply chain issues may not include multi-basis choice-making, for instance, administration level, working expense, assets usage, and so forth. These criteria were various and interrelated. To compose them, AHP will be used to give a deliberate way to deal with leaders to relegate weightings. The optimization results showed that it was reliable and robust.

Chan and Chung [76] concentrated on the coordinated logistics appropriation issue with the interest due to date element. The consolidated AHP–GA methodology was connected to assess and select the best adaptation. Two additional metrics were used to assess the performance of the proposals, in addition to overall costs: overall lead tardiness and time. Chan et al. [77] mulled over the same issue and connected the same technique as Chan and Chung [78]. There is one distinction, which was due to the assessment criteria utilized as a part of the consolidated AHP–GA approach. The efficacy of capacity usage was also considered, in addition to the overall cost, overall lead time, and tardiness.

Moussaoui, et al. [79] measured the energy efficiency of residential buildings using a performance-based approach in the Algerian context. The technique suggested is based on two approaches: top-down and bottom-up. The first one is descriptive down to encourage the recognition of acceptable efficiency indicators correlated with the norm of energy output for residential buildings. The second is a bottom-up strategy based on a weighted sum method of multi-criteria aggregation. A combination approach was used to measure the weights of chosen indicators, based on the method of AHP and GA. The findings showed that the measurements were very interesting and underlined the efficiency of this method. In the majority of cases surveyed, the poor energy quality of Algerian residential buildings has been verified. The proposed optimization of the AHP system using GA yielded very satisfactory results (in particular improvement of the weighting procedure) and allowed a better estimate of the level of energy efficiency.

5.8. AHP-SWOT

Kurttila et al. [80] studied the consolidated AHP with strengths, weaknesses, opportunities, and threats (SWOT) approach in helping the choice making in a Finnish ranger service. There were two choices confronted: (i) make a guaranteed move to certified ranger service; (ii) stay in timber-creation arranged ranger service. To begin with, the key elements concerning this key one was gathered and classified utilizing the SWOT examination. The AHP was then used with the four parameters of the SWOT bunch to measure the relative importance weightings of the SWOT bunch and the weightings of the SWOT elements. The general importance of the variables was derived based on the weightings.

Kajanus et al. [81] studied the joined of AHP–SWOT to deal with answer the topic of whether society can be a winning figure in country tourism or not. The methodology was precisely the same as that introduced before. Shrestha et al. [82] investigated the potential outcomes for Silvopasture reception in south central Florida City utilizing the consolidated AHP–SWOT approach. The authors addressed that Silvopasture is an agroforestry technique that incorporates trees and pasture with livestock activities, which was used by the AHP to quantify the relative weightings of the different SWOT variables. Dissimilar to the past two methodologies, the AHP weightings were acquired as for the key partners including exploration expert, an extensive landholder, and little landholder.

Other than applying to the farming arranging as in Shrestha et al. [82], and Masozera et al. [83] embraced the same way to deal with evaluate the suitability of a group-based administration strategy to the forests reserve of Nyungwe in Rwanda. The AHP was utilized to focus on the noteworthy relative weightings of the SWOT components concerning the key partners. Shinno et al. [84] exhibited the joined AHP–SWOT way to deal with examine the worldwide aggressiveness of Japan's machine device industry.

To explore the inner and outer environments successfully, the SWOT examination was received which involves each of the four SWOT gatherings was further partitioned into three principle sub-gatherings as business sector related, association-related, and item related. As the case with the past methodologies, the AHP was utilized to assess the significance weightings of the key that was calculated for every sub-bunch.

5.9. AHP-DEA

Takamura and Tone [85] displayed the consolidated AHP with the data envelopment analysis (DEA) way to deal with manage the migration of a few administration organizations out of Tokyo. In the first place, the AHP was utilized to acquire the qualities (e.g., the fast reaction in a substantial scale calamity), and the relative significance weightings of criteria (e.g., influence on the fate of the nation). Second, the DEA was introduced to assess the efficacy of different sites in terms of the AHP weightings. Yang and Kuo [86] studied the combined AHP–DEA approach for solving the facility report to create any possible models in advance, a computer-aided layout design technique called Spiral was introduced. The relative significance elective weightings of designs were gotten by utilizing the AHP pairwise correlation concerning three subjective elements: openness, flexibility, and upkeep. The DEA was also used to address the issue of layout design by taking into account both qualitative and quantitative performance details (i.e., flow width, adjacency, and shape ratio) at the same time, contributing to the recognition of value boundaries.

Saen et al. [87] studied the consolidated AHP–DEA way to deal with the relative productivity amount of somewhat non-homogeneous decision-making units (DMUs). Due to the way that some DMUs might don't have at least one component (i.e., yield as well as data), the AHP was used to evaluate the missing worth for a DMU close to reality whatever amount as could be anticipated. So, two alternatives were contrasted with the higher-level point; alternatives include: (i) the DMU that lacks the feature(s); (ii) the other DMUs' sequence implies. The information for a mean of various DMUs was gotten by taking the typical of all components of all DMUs with the exception of the missing substance interesting occasion, and it was assumed that this information was normally conveyed. Ertay et al. [88] implemented the combined AHP–DEA technique, this methodology was somewhat close to that proposed in favor of the facility architecture concept as presented by Yang and Kuo [86].

5.10. AHP–ANP

Pengpeng Xu and Edwin H.W. Chan [89] used analytic network process (ANP) to create, under the EPC system, a blueprint for sustainable BEER. Key Performance Measures (KPIs) for EPC Critical Success Factors (CSFs) and Sustainable BEERs in hotel buildings have been recognized, taking into account the meeting and polling arrangements previously performed by the founders. In this research, through a focus group conversation, the links between sustainable dimensions, KPIs, and CSFs are established. At long last, an ANP model is based in light of the information gathered in the gathering talk utilizing the super decision programming. Joseph Sarkis et al. [90] made a model that uses both the AHP and the ANP as its basis, a sample application is presented to illustrate its viability and usage once the standardized decision model is specified. The strength of the arrangement is exhibited by utilizing the affectability examination, permitting the leader to value the complexities in this choice environment. This work expanded on the moderately scanty formal numerical displaying examination and applications that have major economic, social, and environmental impacts on the sustainability of the built environment of the industry.

5.11. AHP-GIS

Aydi, et al. [91] used the geographic information system (GIS) to develop a logical ranking tool for green stores using AHP. They looked at the regular utilization of the assessment routines for an appraisal strategy of the green store buildings in China, and the green buildings have been created. This technique referenced the rating necessities set by the "China Green Building Evaluation Standard" and weighted each credit for every classification.

5.12. AHP-LCSA

Navid Hossaini et al. [92] examined an AHP based supportability assessment system as the life cycle sustainability assessment (LCSA) for mid-ascent residential buildings in light of extensive environmental and socio-economic criteria.

5.13. AHP-Fuzzy

AHP with fuzzy comprehensive judgment (FCJ) was utilized by Lu et al. [93] in China to decide whether a construction plan complies with low-carbon measures straightforward and rapidly; where Lee S.K. et al. [94] utilized a general review means to recognize and gather the outline criteria that influence the energy interest model and assess the needs of every standard utilizing for the fuzzy and AHP strategy. Furthermore, Chan et al. [95] developed the life cycle assessment (LCA) as a systematic system that incorporates, environmental management accounting (EMA) concepts, FL and AHP, to measure the organizational and environmental presentation of diverse designs. They planned a broadcast model for helping architects' reliance on LCA and a qualitative examination was launched to demonstrate that this methodology gives a methodical technique for assessing option outlines and design improvement options.

Lan et al. [96] analyzing the location using a fuzzy analytical hierarchy process (FAHP) of centrality and the relative weight of the individual component. The outcome seemed the main five pivotal variables that impacted consumers to buy green structures in Taiwan which are the cost of green development, the degree of information on the climate, the expense of green structure content, and how much green use. The consumer's decision making would not be impacted by the green building name, the gender orientation, the natural purposeful publicity of the administration, the estimation of standard society, and financial conditions.

In China, Feng et al. [97] developed a fuzzy-AHP comprehensive evaluation method (FACEM) to be reasonable for the waterfront recovery reasonableness assessment process. They prescribed applying the CRSE process to different territories in China for best administration of waterfront recovery and security ventures. In Macedonia, Donevska, K. et al. [98] combined a fuzzy with an AHP scheme to present a geographic information system based on the multi-criteria selection of sites for non-hazardous municipal landfills in the area of Polog. The frameworks were utilized for preparatory appraisal of the most suitable destinations of the landfill. The outcomes demonstrated that the slightest appropriate landfill range of 1.0% from the aggregate is created when natural and financial destinations are esteemed similarly while a most proper landfill region of around 1.8% territory is produced when the monetary goal is set higher.

Han, T. et al. [41] concentrated on the weighting worth of the light assessment when figured with the fuzzy-AHP strategy. Seong et al. [99] evaluated the key energy advances in contrast to high oil costs utilizing five principles including monetary effect, business potential, improvement cost, internal limit, and specialized twist off. They inferred that the qualified proficiency score of energy innovations against high oil costs may be the crucial choice settling that help leaders in Korea to adequately distribute the available R&D funds. Han, F. et al. [100] developed an arrangement of pointer framework for the assessment of urbanization in rocky range in Xianning (China's city) with AHP using leading a fuzzy thorough assessment of suburbanization for a hilly zone in Xianning.

Hapsari and Subiyanto [101] studied the effective and efficient configuration of the photovoltaic system attached to the building on the academic campus. The design of the photovoltaic system at the project site is based on the roof area and load profile. Five photovoltaic systems were developed using five distinct PV types. Fuzzy AHP used qualitative and quantitative analyses, which can influence the selection process. The systematic standards evaluation consists of the parameters of sizing schemes, the technological, economic, and environmental aspects. The analysis is broken down into 13 sub criteria. From the criteria-based Fuzzy AHP, the findings display the following degree of importance: technological > economic > climate > sizing method. The results indicated that the architecture with monocrystalline and polycrystalline are ideally suited as the least fitting configuration for a photovoltaic device that is connected to the grid and battery energy storage system.

Z. Li et al. [102] used to develop a deliberate strategy utilizing the fuzzy analytical hierarchy process (FAHP) to recognize which distributions inside the city region Ningbo in China have the best capability of conveying green structures, guaranteeing the set targets are reasonable and deliverable. This strategy consolidates a logical cycle, wherein pairwise correlation investigation was directed for the chose standards and viewpoints to decide the weighting elements and scores for each situation. The procedure will be able to adjust changes with the necessities later on to incorporate more models and more targets.

Z. Yan et al. [103] introduced the utilization of AHP and fuzzy engineered assessment strategy dependent on cloud model hypothesis to assess the general activity performance of the green public structures, thinking about indoor climate quality (IEQ) and energy utilization. The assessment strategy covers three standards as target IEQ, abstract IEQ, and yearly energy utilization. Two instances of green and non-green library buildings are practical to be assessed by this strategy, where building supervisors can pass judgment if the structure performs proficiently or not with this assessment technique. This assessment technique can not exclusively be applied to assess the activity performance of various comparable buildings yet, in addition, can be applied to assess similar structures in diverse years. This examination can give specific directing importance to the improvement of the assessment of the thorough activity performance of green constructing.

5.14. EAHP-Fuzzy

The choice of strategies for current building materials cannot give sufficient answers for two noteworthy issues: an evaluation that taking into account the procedure of manageability standards and allocating weights to important appraisal criteria. The Fuzzy Extended AHP (FEAHP) was used by Akadiri et al. [104] to assign and prioritize important weightings for the recognized standards to get a reasonable material choice which rep-resents a significant system in green structure plan. The model utilized an evaluation strategy that was distinguished in light of practical triple bottom line (TBL) methodology and the requirement for building partners. A questionnaire study of building specialists is led to examine the overall significance of the total and measures into six independent evaluation factors. Also, the FEAHP was used by Jian et al. and Lee, A.H. et al. [105] to focus the file weight of six distinct parameters, environment, specific regions, energy, assets, financial, innovation, and society to set up the green degree assessment list framework.

5.15. AHP-Fuzzy-Delphi

The integration of the AHP with the fuzzy technique and Delphi method was found in, for example; Hsueh S.L. et al. [106] principally connected fuzzy-AHP-Delphi in building as a quantitative assessment model for supportable group development for low-carbon improvement adequacy. They used the model to (i) measure numerical values as the base for qualifications and (ii) assess the output of low-carbon public building developments, the city's low-carbon, and energy-saving growth levels are compared.

Furthermore, Liu et al. [107], Liu et al. [108] joined three routines to be added to an extraordinary model for surveying the energy-saving design of private buildings in Taiwan. They found that joining double-skin facades, green roof, and solar building materials can adequately give high energy-saving outlines utilizing applying (a) the Delphi decision-making strategy to give a co-design feature; (b) to translate complex interior and outer factors into straightforward rates or proportions that advance choices, the AHP can incorporate multi-criteria decision-making and (c) fuzzy logic theory.

Moreover, Hsueh S.L. et al. [109] utilized the Delphi system, fuzzy logic, and AHP (DFAHP) as an evaluation to redevelop the neglected public buildings. Alapure et al. [110] established a model for evaluating the sustainability of traditionally constructed structures through utilizing AHP, Delphi, and fuzzy logic hypothesis for choice-making checked to utilize the physical estimations through meeting based on a survey in India.

5.16. AHP-Fuzzy-GRA

The AHP-fuzzy-GRA combined approach is better to be applied in a complex decision process, which frequently seems OK with subjective information or vague data as utilized by Gumus A.T. et al. [111]. They proposed a Buckley expansion-based- (Fuzzy-AHP) and a direct standardization-based-fuzzy-gray relational analysis (Fuzzy-GRA) that joined with multi-criteria decision making (MCDM) system for unraveling hydrogen energy storage (HES) choice issue in Iran with distinctive defuzzification routines. Also, Wang et al. [112,113] examined the probability of utilizing Fuzzy-AHP with fuzzy-GRA for the ideal determination of competitor tenderers in the procedure by the concern of a fuzzy hybrid environment with deficient weight data. The scheme was proposed and tested in Turkey to get aggregate different types of evaluated information and the exact weight information and to determine the best candidate for tenderers.

5.17. AHP-Fuzzy-IRP

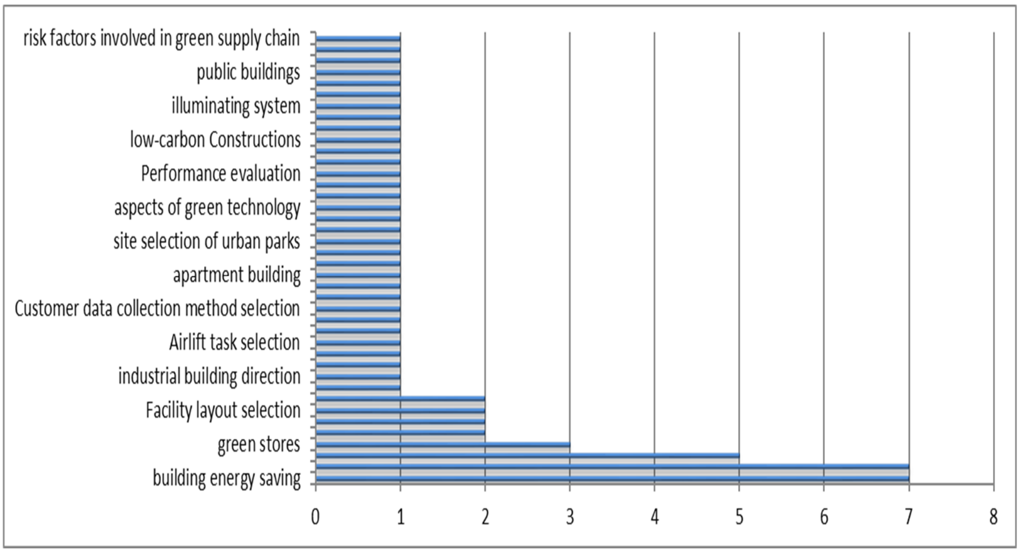
Mangla S.K. et al. [114] assessed that a few distinctive danger calculations are dealing with green supply chain (GSC) problems effectively. These risks tend to interrupt and thus reduce the performance rate of traditional GSC operations. They moderated the results, by displaying which could assess the dangers in the setting of GSC is required from the industrial perspective. This analysis aimed to introduce a scalable decision model based on the framework of the combined fuzzy-AHP and interpretive rating process (IRP) to determine the risks associated with the application of GSC activities in the fuzzy setting. The fuzzy-AHP approach estimates the positioning of the distinguished risks or the need by deciding their overall significance. Then, to explore the risk situating got past the fuzzy-AHP, the way of thinking of IRP is connected. However, the IRP approach also helps decision-makers to comprehend the interpretive rationale for the superiority of one risk over the other for each pairwise distinction. The proposed adaptable risk assessment model is applied to an exact instance of an Indian poly plastic assembling organization.

6. Results and Discussion

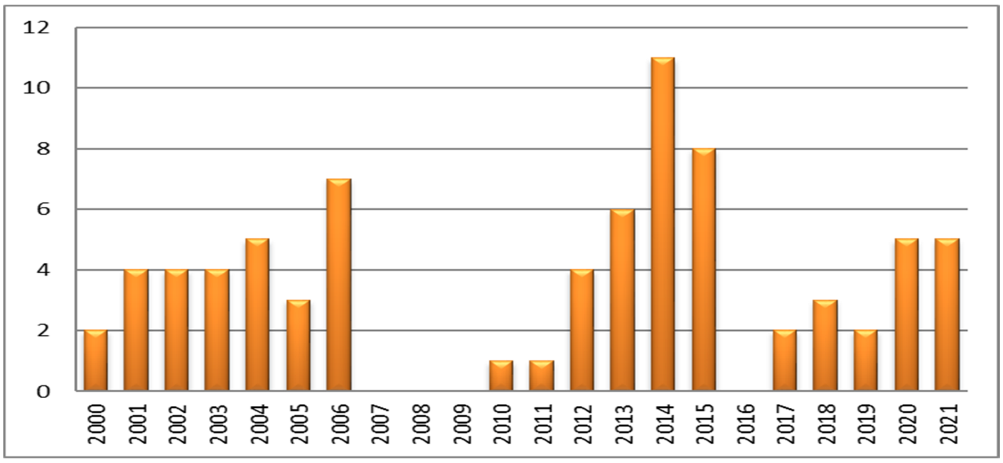
The translated article shows the application of Thomas L. Saaty's AHP method [42] for an overview of literary sources concerning the creation of green buildings, green architecture with an emphasis on the use of non-traditional energy sources. It is an overview of the literature in this area with emphasis on its use in engineering practice [88,115,116]. Specific examples from different countries are shown [117,118].

The paper introduces some environmental and physical design approaches for green buildings to improve plan boundaries and decision-making problems. In this regard, the consider displays an investigation from claiming effects to investigate the worth of effort that utilized the AHP procedure; Furthermore, its combinations similarly to a streamlining plan in the field of green architecture/building plan.

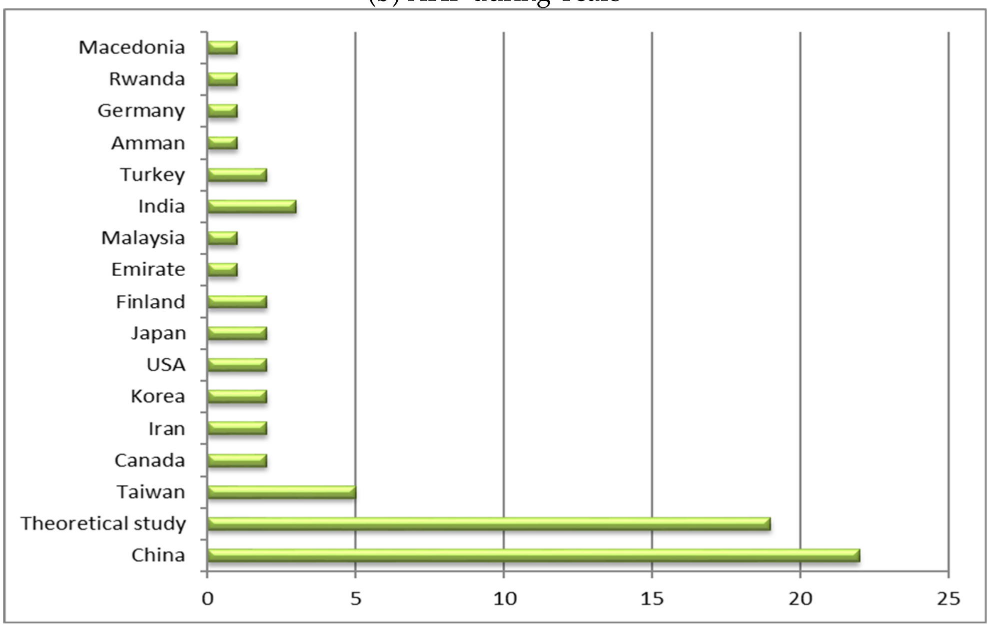
Figure 2 presents graphical data on the works included in the main summary Table 1. The figure sums up the essential statistics of the latest 84 studies on analytical hierarchy process frameworks and their combinations with numerical programming approaches and their applications from 2000 to 2021.



(**a**) Objectives

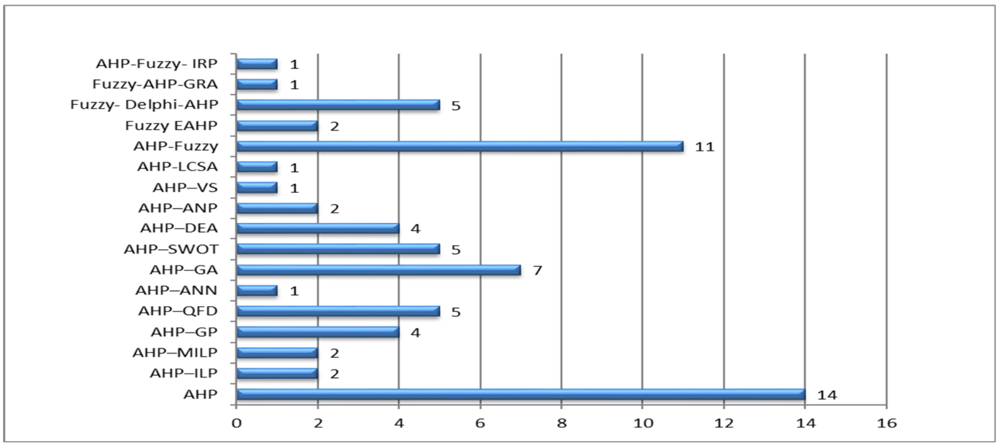


(**b**) AHP during Years

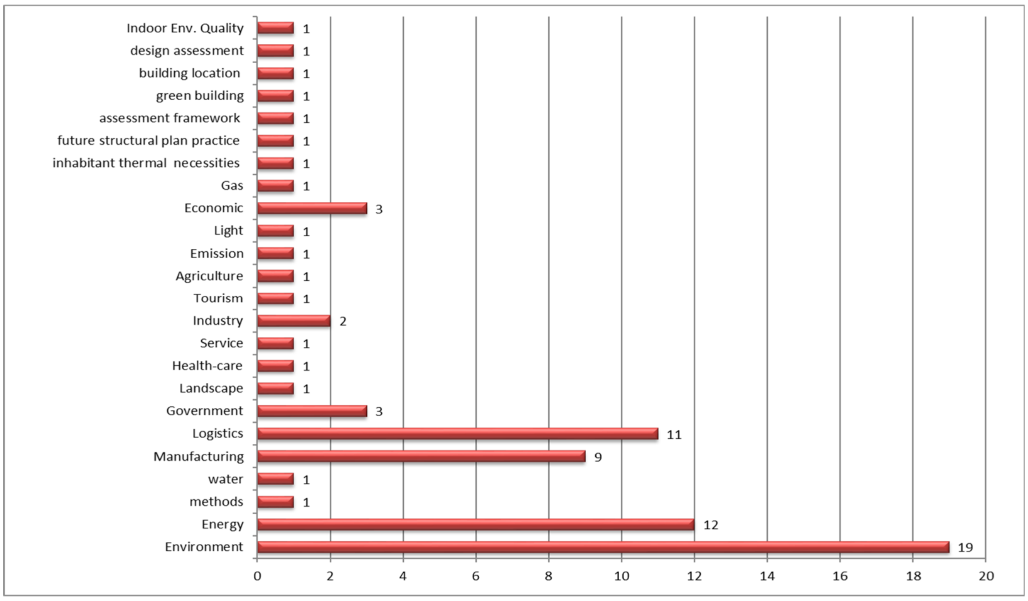


(**c**) AHP studies in countries

Figure 2. *Cont*.



(**d**) AHP and its combination schemes



(**e**) AHP Applications

Figure 2. AHP graphical information (**a**) AHP objectives, (**b**) the AHP during years, (**c**) the AHP studies in countries, (**d**) the AHP and its combination schemes and (**e**) AHP Applications.

Figure 2a shows that the AHP scheme is used for many objectives for promotion and enhancement in the field of green building; where the most objectives of the research papers are in the building energy-saving and promoting green building that represents (70%) from all of the research objectives that depend on AHP. Also, Figure 2b shows that the ultimate number of researches works that used the AHP technique during the 20 years and it is clear that the algorithm is widely used mostly in 2014.

Analytical hierarchy process techniques are built as a theoretical solution to some problems such as optimization in percent of (15%), but most countries that used these techniques are China (19%) and Taiwan (5%) as in Figure 2c. In Figure 2d the integrated analytical Hierarchy Process with other mathematical programming techniques is presented; was (15%) used the analytical hierarchy process as a mathematical programming technique only, and (15%) used analytical hierarchy process combined with fuzzy as the most two schemes are usually used. Twenty-eight percent (28%) of papers focused on environment applications, where (16%) focused on logistics as the most applications used as shown in Figure 2e. From this discussion, it is obvious that AHP is a trusted scheme for optimization that most researchers depend on it to solve their problems.

Accordingly, to enhance our results, we add a benchmark comparison with one of state-of-art paper [23] that is most suitable with our review process. The results are shown in Table 2.

Table 2. Comparison between our study vs. ref. [23].

No. of Papers	Ref. [23]	Our Study
Scope of work	Constructions	Green Buildings
No. of papers	77	117
Covered of Years	2004–2014	2000–2022
No. of Countries	22	17
The highest year of publication	2007	2014
The location of highest conducted research	USA	China
Published	Taylor & Francis	MDPI

So, the AHP can help stockholders, planners, and architects to simplify the design for the green building outline, for whoever they employ to consider perfect solutions for green plan building outline advancement and utilization.

7. Limitations of This Study

This study is the first phase of a literature review that study AHP's application in green building design from various perspectives. However, it does not include application examples that show how AHP can be used step-by-step to solve specific problems in the studies identified. Also, the articles provide a good reference point for understanding how AHP was employed to address a specific problem. Furthermore, future reviews will cover articles published till 2022 and articles interested in analyzing the software techniques to create bibliometric networks in order to better understand the literature.

Furthermore, while it was simple to identify and categorize AHP application areas using the topic coverage of the evaluated articles, the approach was heavily reliant on the authors' subjective assessments. Finally, research is needed to distinguish between AHP and other multicriteria decision-making approaches by evaluating their benefits and demerits in various green construction scenarios to identify which methods are preferable to the others.

8. Conclusions and Future Work

This paper contributes a comprehensive state-of-art review for the current late artificial intelligence-based practices (2000–2021) using strategies, technologies, models, and techniques that have been used in the green building for analysis in order to find the best green building solutions, strategies, and models. The paper demonstrated that a rising trend of interest in optimization is maintained since businesses and manufacturers understand the high capability of the AHP approach and its combinations (for example, Fuzzy and GA schemes) since they are confronting more severe challenges than ever. More increasing demand to achieve environmentally and economically design needs more optimization techniques to achieve all of the demands.

It is noticed that the AHP integrated methods are applicable, effective, and efficient in the field of sustainable green building in a diversity of environmental and research problems related to green building. It was observed that the AHP technique when combined with other models or techniques such as ILP, MILP, GP, QFD, ANN, GA, SWAT, DEA, ANP, VS, LCSA, FUZZY, EAHP, DAHP, GRA, and IRP yields a more helpful methodology for the vast majority of pragmatic amounts and subjective applications such as a model of quantitative examination for reasonable gathering improvement and low-carbon improvement viability. Based on this review, these recent technologies are widely used in developed countries such as China, Taiwan, Canada, Iran, Korea, and The USA while in developing countries it is still not broadly utilized. Also, the benchmark shows that we used many research papers with 40 papers increased than the state-of-art paper review in the same subject.

In future work, we will consider some of upcoming AHP purposes that could focus on building expertise managing outlines to find new processes, schemes, customs, and tools essential for implementing knowledge strategies in green building design.

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Conflicts of Interest: The authors declare no conflict of interest.

Nomenclature

CSW	Compressed Shopper Waste	SNS	Spallation Neutron Source
AI	Artificial Intelligence Algorithms	DEA	Data Envelopment Analysis
GA	Genetic Algorithms	DFUZZY	Delphi-Fuzzy Method
MILP	Mixed Integer Linear Programming	FCJ	Fuzzy Comprehensive Judgment
ILP	Integer Linear Programming	R&D	Research and Development
AHP	Analytic Hierarchy Process	GRA	Grey Relational Analysis
GP	Goal Programming	ANP	Analytic Network Process
QFD	Quality Function Deployment	LCA	Life-Cycle Assessment
LCSA	Life Cycle Sustainability Assessment	CBA	Choosing By Advantages
G-SEED	Green Standard for Energy and Environment Design	GIS	Geographic Information System
LCC	Life Cycle Cost	FL	Fuzzy Logic
ANN	Artificial Neural Network	EBP	Error Backpropagation
TS	Tabu Search	DMUs	Decision-Making Units
EPC	Energy Performance Contracting	IRP	Interpretive Ranking Process
KPIs	Key Performance Indicators	CSFs	Critical Success Factors
SWOT	Strengths, Weaknesses, Opportunities, and Threats	EMA	Environmental Management Accounting
MCDM	Multi-Criteria Decision Making	TBL	Triple Bottom line
HES	Hydrogen Energy Storage	GSC	Green Supply Chain
EAHP	Extended Analytical Hierarchy Process	FACEM	Fuzzy-AHP Comprehensive Evaluation Method
BREEAM	British industrial building and domestic green building.	FAHP	Fuzzy Analytical Hierarchy Process
CRSE	Coastal Reclamation Suitability Evaluation	EUL	Egyptian Universities Library
MCMP	Multi-Criteria Mathematical Programming	FEAHP	Fuzzy Extended Analytical Hierarchy Process
RT	Real-Time		

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