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Application of Artificial Intelligence in Green Building Design

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ABSTRACT:

Green building design is a result of carefully designed spaces which consider ventilation, daylight, energy, water, etc. To achieve a green building compliance simulations, calculation and different options are tested in software in order to take right decisions. The role of computer analysis plays a major role in decision making and show the evidence of the favourable result achieved. When a building meets all the requirements of rating systems, it achieves a green building certification. Artificial intelligence is an advancement in Computer technology serving architects, engineer and designers a wide scope of work faster and reliable. Artificial intelligence (AI) applied to green buildings might be the answer to the global problems of sustainability. AI is the field of study and development focused on creating intelligent computers capable of reasoning, learning, communicating, planning, moving, manipulating objects, and solving problems. Artificial Intelligence (AI) offers several advantages, including the improvement of production and communication. This research focuses on the scope of Artificial Intelligence which can be helpful in green building design and compliance to rating systems. The methodology of the research is based on systematic review of Scholarly articles and literature to find the available tools, scope, applications, potential, current trends and future scope. The research study also explores literature in which artificial intelligence technology was applied or can be applied in green building design. The paper concludes with findings and discussion of artificial intelligence in green building industry.

Keywords: Artificial Intelligence, Building Design, Green Building, Sustainability, Technology

1. Introduction

Green Building Design is achieved by multiple analysis of building performance in terms of energy, water, daylight, ventilation, and lighting, etc. Green rating systems such as GRIHA (Green Rated Integrated Habitat Assessment), IGBC (Indian Green Building Council), WELL, LEED (Leadership in Energy and Environmental Design), Green Star, Green Mark and BREAM (Building Research Establishment Environmental Assessment Method) provide standards, criteria or benchmarks in which points are assigned and accordingly rating is given to the building. The rating systems focus on a building's ability to achieve sustainability, energy efficiency, reduction in environmental impact, limit use of limited resources and rely on renewable sources, address climate change, and many more. Thus, to achieve a green rating the building design must undergo monitoring, multiple analysis and decision making based on analysis done. [5].

The research question is that what is the suitability of AI tools in green building design, what options are available, and what is their feasibility? Various software applications are used in analysis and simulation of building design. This software is capable of analysing climate, surface radiation, wind flow, daylight factor, energy consumption and artificial lighting. Software such as Autodesk, Sketchup, Rhino, DiaLux, Ecotect, IES VE, Design Builder, EnergyPlus and suitable plugins of these software. The aim of the research study is to find out Artificial Intelligence tools which are useful for Green Building Design. The objectives of the study are to identify the available AI tools and there use in green building design, to analyze the viability of the software along with its benefits and limitations.

2. AI-Driven Approaches to Green Building Certification:

Artificial Intelligence (AI) is becoming an essential tool in green building design, fundamentally transforming the approach of architects and designers to sustainable construction. AI provides significant advantages in this domain, particularly by enhancing energy efficiency, optimizing material choices, and improving overall building performance. An important use of AI in green building design is the utilization of generative design algorithms. These algorithms enable architects to examine numerous design possibilities that adhere to particular limits and limitations. AI algorithms may utilize environmental data, energy usage trends, and other variables to produce inventive design solutions that priorities sustainability and energy efficiency. [12].

Furthermore, simulation tools driven by artificial intelligence (AI) are essential in assessing the performance of buildings and pinpointing areas where enhancements may be made. These technologies have the capability to replicate elements such as daylighting, natural ventilation, and thermal comfort in order to enhance the quality of the interior environment while reducing energy usage. In addition, AI enables the conduction of life cycle assessments (LCAs) for building materials, assisting architects in making well-informed choices about material selection and construction techniques in order to minimize environmental consequences.

In addition, AI-powered systems allow architects to effortlessly incorporate sustainability ideas into the design process. These platforms offer immediate feedback and suggestions on design tactics, material selections, and building methods that promote energy efficiency. Through the utilization of artificial intelligence, architects have the ability to design buildings that not only reduce energy usage and carbon emissions, but also improve the comfort and well-being of the occupants.

The integration of AI in green building design signifies a substantial advancement in the development of sustainable and ecologically conscious constructed spaces. [12]. 3Through the utilization of AI algorithms and simulation tools, architects may create structures that not only fulfil present requirements but also make a positive impact on the environment for future generations. [1]

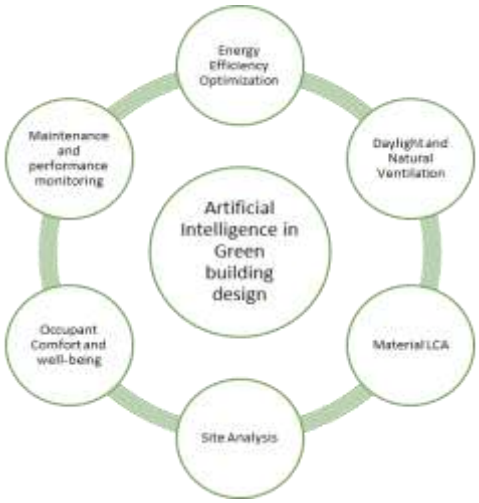

Figure 1: Use of AI in green building design and analysis

Source: Author

Artificial Intelligence (AI) is essential for advancing sustainable architecture since it improves the design process, optimizes building performance, and enables well-informed decision-making. The following outlines the ways in which AI helps to sustainable architecture:

1. Energy Efficiency Optimization: AI algorithms incorporate building data, including energy consumption trends, weather conditions, and the occupant behavior, to optimize energy utilization and minimized inefficiency. Minimizing energy use and environmental effect by simulating different situations and suggesting energy-efficient design ideas.

2. Daylighting and Natural Ventilation: Artificial intelligence-powered simulations assess daylighting and natural ventilation methods to optimize the utilization of natural light and airflow in buildings. It is possible to optimize interior environmental quality and enhance occupant comfort by analysing building orientation, window location, and shading devices. This analysis also minimizes the requirement for artificial lighting and mechanical ventilation.

3. Material Selection and Life Cycle Assessment: AI tools evaluate the ecological consequences of construction materials across their whole lifespan, taking into account aspects like resource extraction, production procedures, transportation, and disposal at the end of their useful life. Life Cycle Assessment enables decisions that minimized embodied carbon and support circular economy concepts by offering insights into the environmental impact of various materials.

4. Site Analysis and Urban Planning: AI algorithms are beneficial to utilize geographic data, urban patterns, and environmental elements to provide insights for site selection, urban planning, and landscape design. Forecasting microclimatic conditions, evaluating the distribution of green spaces, and recognizing potential for using passive design solutions.

5. Occupant Comfort and Well-being: AI-driven building management systems monitor indoor environmental conditions, occupancy patterns, and user feedback to optimize comfort and well-being for building occupants. By dynamically adjusting HVAC systems, lighting levels, and acoustic conditions based on real-time data and user preferences, AI enhances occupant satisfaction, productivity, and health while reducing energy consumption.

6. Predictive Maintenance and Performance Monitoring: AI algorithms analyze building performance data, sensor readings, and maintenance logs to predict equipment failures, identify inefficiencies, and optimize building operations. By implementing predictive maintenance strategies and continuous performance monitoring, AI helps reduce downtime, extend equipment lifespan, and improve overall building efficiency and resilience.

3. Methodology

The research study employs a technique that relies on secondary data and a comprehensive evaluation of scholarly articles and journal papers. An extensive examination of the use and implementation of Artificial Intelligence techniques for the purpose of designing and certifying environmentally-friendly buildings. The study assesses several techniques for the utilization of AI in the design of environmentally-friendly buildings. Given that AI is a relatively new technical development, the research articles from the past five years will be examined. In addition, the official websites of the software companies will be reviewed for information. Analysis and Inferences will identify the gaps in literature and summaries the findings.

4. Literature Review

A paper by I Alecrim, et.al demonstrates the integration of Building Information Modelling (BIM) and Life Cycle Assessment (LCA) offers a new approach to automate the evaluation of the impact on the environment in the building sector. [4] Although previous research has been conducted, there is still an urgent need to establish a universally accepted evaluation framework and suggested software tools for Life Cycle Assessment (LCA) inside the Building Information Modelling (BIM) approach. This study assesses the present condition of Life Cycle Assessment (LCA) integration in the Building Information Modelling (BIM) procedure and contrasts outcomes obtained from two LCA software tools: Athena Impact Estimator and Tally. The research examines the interoperability, user-friendliness, and environmental impact assessment capabilities of both technologies by using a case study created in Autodesk Revit. [4]

Tally exhibits exceptional compatibility and user interface, whilst Athena Impact Estimator showcases an extensive materials database and meticulous construction characterization prerequisites. [4] The research aims to quantify environmental impacts using selected indicators such as Global Warming Potential (GWP) and Acidification Potential (AP) by following the EN 15978 methodology, which includes material production, construction, use, and end-of-life stages, as well as the ISO 14044 standards for goal definition, inventory analysis, impact assessment, and results interpretation. (I Alecrim, et.al. 2020) This study highlights the possibility of improving Life Cycle Assessment (LCA) procedures by including Building Information Modelling (BIM), providing valuable information on choosing appropriate software and considering methodological factors for conducting thorough environmental impact assessments in building projects.

A paper by J. Q. Huda Mohamed Ibrahim El-Baz examines a case study of a Coastal Villa in New Damietta, Egypt, and Revit software with AI capabilities are used on zero-energy construction strategies in new cities. In light of global climate change, coastal cities must reduce non-renewable energy use. The project intends to offer urban zero-energy construction concepts by emphasizing clean, sustainable energy sources and their significance in environmental sustainability. The research uses Revit software and LEED standards to measure building energy efficiency to meet Egypt 2030 sustainable development targets. The research shows that zero-energy construction designs may reduce carbon emissions and provide environmental resilience via theoretical inquiry and practical implementation, including field tests and computer simulations. The planned Coastal Villa in New Damietta shows how passive architecture, renewable energy systems, and energy-efficient HVAC solutions can create a greener future. The research emphasizes the importance of multidisciplinary methods and technical advancements like AI-powered design tools in sustainable architecture and urban development environmental mitigation.

The research paper by Chen, Zheng & He, Yu. discusses the crucial problem of worldwide environmental pollution caused by the building industry and emphasizes the pressing necessity to reduce its negative impacts. [2] The project seeks to optimize green building techniques and mitigate environmental harm by utilizing artificial intelligence (AI) technology. The research examines various automatic control systems that can be applied in the design, construction, and operation of buildings by analyzing existing information models such as Building Information Model, Machine Learning, Deep Learning, Response Surface Methodology, Multi-Agent System, and Digital Twins. The research highlights the fundamental concepts of sustainable building, including optimal energy efficiency, efficient resource allocation, environmental compatibility, and ensuring resident comfort and safety. Furthermore, it emphasizes international benchmarks for sustainable building practices, such as China's GB/T50378-2014, and emphasizes the significance of integrating environmental factors into the stages of planning and construction. [2] The study recognises that while AI has the potential to improve environmental performance and energy efficiency in building, there are problems associated with cost implications and economic feasibility. However, the report highlights the need of using AI technologies to enhance the efficiency of green building design, construction, and operation processes. It also emphasizes the necessity for more research to investigate other combinations of information models for sustainable construction practices. The study provides significant insights and recommendations that contribute to the continuing discussion on green building. It highlights the crucial role of AI technology in tackling environmental concerns and promoting sustainable development goals.

5. Artificial Intelligence tools

Several Artificial Intelligence tools and platforms can be utilized for green building design, each offering unique capabilities and features. Following are the AI tools used in green building design:

5.1. Autodesk Generative Design:

Autodesk's generative design tools leverage AI algorithms to explore numerous design options and optimize building performance, including energy efficiency and sustainability. Generative design uses input goals set by the designer and creates the design output. Autodesk has a large number of products. Out of all products, the AI powered design tools are identified with special focus on green building requirements.

Autodesk Forma: It is a cloud-based software that performs Real time analysis of wind, energy and noise can be done using this software. The software is suitable for early-stage planning and design. The software provides time efficiency of 50-65% reduction in time required to develop conceptual design. The subscription cost is around INR 81,000/- for one year

Autodesk Infodrainage: InfoDrainage is a comprehensive design and analysis tool for stormwater drainage systems and hydrological simulations and cost effectiveness. Drainage design requires consideration of topography, construction materials, hydrological data. Display of real time animation and objects. The results obtained from input data can be exported in various formats. This software is mostly beneficial for floodline detection, pipe design, drainage layout, and storm water design. The subscription cost is around INR 2 lakhs for one year

5.2. Green Building Studio:

Green Building Studio, part of Autodesk's suite of tools, utilizes AI and cloud-based simulations to assess building performance and optimize energy efficiency, daylighting, and thermal comfort during the design phase. It assists in whole building performance analysis which compliances to the national codes of countries such as ECBC code of India. Whole building analysis includes thermal analysis, operational cost of building, climate, daylight and ventilation, form analysis: surface radiation, HVAC, Lighting, equipment heat gains, energy and water calculations.

5.3.Sefaira:

Sefaira is a cloud-based software platform that integrates with building information modeling (BIM) tools to analyze and optimize building performance in terms of energy, daylighting, and thermal comfort using AI-driven simulations. It is a plugin which can be used in Autodesk Revit and Trimble Sketchup software. Comparative analysis results are generated of conceptual design options and you can decide the best option. The results can be displayed in charts and tables. The software assists in identification of critical spaces of the building and solutions can be provided and enhanced design is possible. The software uses ASHRAE and other industry standards for simulation. The subscription cost is around INR 1.6 lakhs for one year

5.4. Tally – Autodesk Revit:

Life cycle assessment is used for analysing the performance of material from the manufacturing stage to the end or disposal. A material has significant impacts on the environment during its manufacture, use and disposal. Tally is an AI-powered tool that use life cycle assessment (LCA) to assist architects and builders in assessing the ecological consequences of building materials and construction techniques. This allows for well-informed choices to be made in order to reduce carbon emissions and support sustainability. Tally support Autodesk Revit software as Revit analyses each element as a material, it is easy to perform LCA simulations.

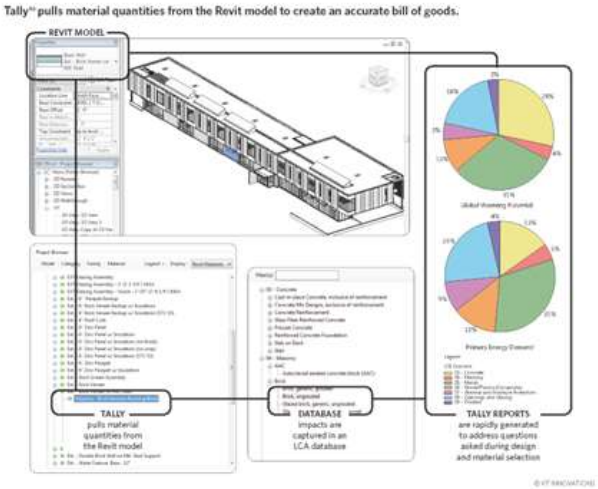

Figure 2: Tally AI Building analysis

Source: https://apps.autodesk.com/RVT/en/Detail/Index?id=3841858388457011756

5.5. Honeybee:

Honeybee is an open-source platform that integrates AI algorithms with building performance simulations to assist architects and engineers in designing sustainable buildings with optimized energy usage and environmental impact. Honeybee software helps architects, engineers, and designers with advanced environmental analysis, modelling, and optimization for building design and urban planning projects. Honeybee integrates smoothly with Rhino and Grasshopper to study building performance indicators including daylighting, solar radiation, energy consumption, thermal comfort, and airflow dynamics. This comprehensive platform lets designers examine design alternatives and parameters to modify building designs, materials, and systems for sustainability and occupant well-being. Honeybee promotes LEED and BREEAM certifications by using data-driven insights and evidence-based decision making to ensure projects satisfy strict sustainability criteria and benefit the built environment. Honeybee encourages multidisciplinary cooperation, creativity, and energy-efficient, ecologically sensitive, and resilient buildings and communities with its user-friendly interface and tremendous capabilities.

5.6. Ladybug Tools:

Ladybug Tools is a collection of open-source plugins for environmental analysis and simulation in building design. It includes AI-driven tools for daylighting analysis, energy modeling, and thermal comfort assessment to support green building design practices. Ladybird Tools is an accomplish Grasshopper and Rhino environmental analysis plugin used in architectural and urban design projects to optimize building efficiency. Solar radiation analysis, daylighting research, energy modelling, outdoor comfort analysis, and climate-based design optimization are its functions. Ladybird Tools helps designers make educated decisions and create performance-driven designs by simulating and visualizing environmental circumstances. By incorporating environmental research directly into the design workflow, Ladybird Tools helps architects and engineers explore design choices for more sustainable, energy-efficient, and pleasant buildings. Its user-friendly interface, extensive library of analysis components, and seamless integration with Grasshopper make it essential for professionals looking to improve design quality and environmental performance while meeting sustainability goals and regulatory requirements.

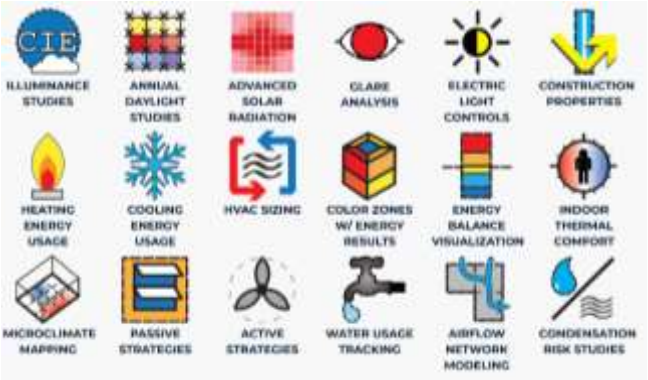

Figure 3: Analysis which can be done by Ladybug tools

Source: https://www.ladybug.tools/

5.7. Sidewalk Labs:

Sidewalk Labs' AI software aims to transform urban planning and development by utilizing artificial intelligence to establish cities that are more efficient, sustainable, and focused on the needs of people. The programmed combines data analytics, machine learning, and predictive modelling to enhance several elements of urban living, such as transportation, energy consumption, trash management, and community involvement. Sidewalk Labs' AI software utilizes extensive data from sensors, IoT devices, and urban infrastructure to discern patterns, trends, and insights, which may be used to guide decision-making and policy development. The advantages encompass the capacity to augment mobility and accessibility, diminish environmental repercussions, increase public services, and cultivate inclusive and dynamic urban communities. Through the use of AI-generated insights, urban planners and politicians may make informed decisions based on data to tackle intricate urban issues and develop cities that are more habitable, environmentally friendly, and adaptable to future uncertainties.

5.8. ClickUp:

It is a productivity and project management tool, employs artificial intelligence (AI) to enhance its functionality and optimize user experience. AI systems streamline repetitive tasks, enhance operational efficiency, and provide tailored recommendations by analysing user actions and preferences. ClickUp's AI is useful in efficient project management. ClickUp's user-friendly interface and AI-driven features enhance team collaboration, visibility, and adaptability, hence enhancing project results and organizational effectiveness.

These AI-powered tools and platforms empower architects, designers, and engineers to make informed decisions, optimize building performance, and create environmentally sustainable structures that contribute to a more sustainable future.

6. Benefits of use of Artificial Intelligence tools studied above:

- Supports sustainable development and green building goals
- Provides ease of work and understanding for new learners.
- Plugins can be used with existing software which are already being used in the Architecture and construction industry. This saves additional skill requirement.
- Data analysis is easier to interpret in forms of graphical representation
- The results can be exported in desired format required to submit to the green building rating system.
- Complex calculations and management are easy to handle and data is reliable.
- AI driven tools have standards such as ASHRAE and other standards preloaded into the software, this helps in designing to the requirements with minimized errors.

7. Limitations of use of Artificial Intelligence tools studied above:

- Latest graphic card requirements generally past 3-4 years are eligible.
- Requires monitor resolution.
- Cloud based software require high internet connectivity.
- Artificial Intelligence Plugin tools require latest versions of parent software

8. Future Need of Development in AI for Green Buildings

- Educational Versions of AI tools are required. Free trials must be available for use.
- There is need of AI in enhancing the efficiency of green buildings during construction and operation phase. Evaluation at this stage needs to be developed.
- AI driven tools for sustainable construction practices
- The user interface should be simple and universal as there is lack of skill.
- Linkage between multiple software is essential
- AI needs to enable comparative analysis with more easy graphical understanding.
- AI compatibility with various software is required.
- Need of AI plugins to parent software reduces cost and time for extra learning. If the software is separate, it must consist whole building analysis, thus it will be economical for subscription purchase.
- Cloud based AI tools must support previous versions of computer configurations.
- AI needs to detect errors in design and provide suggestions.
- Generating reports for Green Building certification will be additional benefit.
- AI tools must link with Google Earth for site analysis and real time data.
- BIM is emerging as a technological advancement; thus, BIM and AI must collaborate and develop with compatibility to each other.

9. Conclusion

The research study reviewed secondary data, official websites, guidelines, product specifications, and scholarly papers to emphasize the significance of AI-driven technologies in Green Architecture. The article provides a comprehensive guide for architects and green building consultants to investigate the current alternatives by explaining each tool in detail. Architectural work is a perpetually demanding task, and including green building research increases the workload, resulting in additional time requirements. As the duration of project design increases, it becomes less cost-effective. Optimizing time efficiency is important in the process of construction design and implementation. AI tools function as time-saving devices while also improving the

precision of projects in attaining green construction objectives. The study indicates that AI is increasingly seen as a crucial instrument for decision making in the design and analysis of green buildings.

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