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Innovation and Efficiency in Smart Architecture: A Focus on Sustainable Building Design

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ABSTRACT

Smart and sustainable architecture has transformed the construction industry, fostering environmental awareness and efficient use of resources. This research analyses the social impact of smart practices in the design of sustainable buildings. A qualitative, non-experimental methodology was used, examining documentary sources and real projects such as Pixar Building, Suzlon One Earth, and Bosco Verticale, all of which are LEED certified for sustainability. The findings reveal that sustainable design optimizes the use of natural resources, reduces environmental impact, improves efficiency, and decreases dependence on polluting energies. These projects not only improve the physical environment, but also increase environmental awareness and foster social development, generating spaces that contribute to collective well-being. In conclusion, sustainable architecture effectively addresses environmental challenges, while promoting more equitable and environmentally responsible social development, positioning itself as a key strategy for the future of urban design.

1. INTRODUCTION

Globally, methods for achieving sustainability in architecture have continuously entered the architectural scene with different conceptualizations of the link between the elements of the tripolar model: society, environment, and economy. While in the past designing sustainably was implicitly on our agenda most of the time, today there is a call for precise methods or tools to achieve sustainable models [1]. This challenge triggered a series of challenges in the construction sector, including the search for sustainable projects with the highest possible energy rating [2].

Specifically, in South America, the new approaches to the conceptual design of buildings must necessarily foresee the confluence of the construction principles composed of: energy, water and materials; the same ones that will fulfill the bases of an architecturally sustainable building [3]. At this point is where the intelligent designs of modern buildings are identified, whose approach denotes the conservation of energy resources, in addition to promoting the use of new technologies, which is associated with the potential useful life of natural resources [4, 5].

Considering the expansion of the use of sustainable and intelligent buildings, Zebari and Ibrahim [6] refer that the most pressing problem facing the environment of most buildings is humidity and air temperature, caused by little or no insulation to achieve the level of thermal comfort necessary in each season. Under this premise, Zhong et al. [7] state that sustainability and technology come together in architectural design to consolidate a comfortable environment, managing to integrate resources that will facilitate the use and functionality of these buildings in the long term [7-10].

The exploitation of the diverse resources that South America presents, unlike other parts of the world, has meant that their preservation is not considered, which has generated wear and tear on them and only now is sustainable construction through technologies that manage to intelligently exploit these resources considered as a factual solution [11, 12]. Therefore, Al-Saggafa et al. [13] maintain that multiple researchers have concluded that the demand to reduce energy consumption appears to be the most important aspect of the initial stage when designing a project [14-16].

The present research aims to analyze the social impact of the adoption of intelligent architecture in the design of sustainable buildings, taking as a reference the Pixel Building, Suzlon One Earth, El Bosco Verticale, as well as describing its evolution over the last 5 years and the benefits provided at the country level.

The study is justified by its contribution to knowledge about the incorporation of emerging technologies in architectural design, whose social impact focuses on improving the quality of life and community well-being through greater public awareness by investing in the construction of sustainable buildings. This research is based on the analysis of emblematic cases obtained from the LEED global certification program, from countries such as Australia, India and Italy. Through this approach, it is intended to broaden the understanding of how these innovative practices can be used as reference models, with the aim of expanding their application in Latin America. This analysis seeks to promote social equity through the inclusion of sustainable criteria that benefit the community, improving housing conditions and generating a positive impact on the urban environment, so that a balance is achieved between architectural development and the social needs of the continent.

2. LITERATURE REVIEW

Considering the opinions of various theorists, intelligent architecture is defined as a system capable of interacting with its environment, becoming a sustainable building. Likewise, Konig et al. [17] consider that the use of technologies makes production processes more efficient in such a way that solutions can be developed to the different threats that may affect the performance of a sustainable construction. Smart architecture manages to encompass in its concept the theory of sustainability regarding future construction designs [18-23].

On the other hand, Pardo-García et al. [24] argue that an intelligent architecture or building must consider a productive and efficient work environment through the optimization of its structure, systems, and resource management, with the corresponding interrelations between them. Other specialists such as Kroner [25] consider that an intelligent design goes hand in hand with sustainability, taking advantage of new technologies and thus being able to improve the quality of life, efficiency, and urban services, in addition to covering all the needs of present and future generations, in environmental, economic and social aspects [13, 26-28].

Studies carried out in various regions of the world indicate that smart architecture is emerging as a key tool to optimize environmental, material, and economic efficiency, promoting sustainable building models that maximize their development potential [29-32]. Architectural design strategies are essential for the advancement of the real estate sector; furthermore, the creation of new technologies and materials applied intelligently contributes to significantly reducing the environmental impact [18, 33-36].

Due to the increasing impact of climate change in recent years, several countries have developed strategies to significantly reduce the environmental impact of the construction sector, establishing as key objectives the use of sustainable indicators, such as the reduction in resource consumption, the reuse of materials and, especially, energy efficiency and rationality [37-41]. Furthermore, other studies directly link these strategies to sustainable design, integrating essential aspects such as lighting, ventilation and building maintenance, among other determining factors [42, 43].

The model proposed by Osma and Ordóñez [44] suggests that, in the design of buildings, it is possible to implement various sustainable applications through methodologies that promote the rational use of energy. Among the tools considered, the concept of exergy stands out, recognized as the most appropriate for this purpose. These applications are classified into two types: active, which include photovoltaic solar energy, wind energy and grey water treatment; and passive, such as natural lighting, natural ventilation and green roofs. Thus, two fundamental approaches are identified in sustainable design: passive design and active design.

On the other hand, the dimension referring to active design directly applies new technologies for harnessing renewable energy, such as solar, wind or biomass energy. This section would also include all energy saving systems for traditional equipment, such as those involved in cogeneration plants, which require energy for their correct operation. It should be emphasized that active systems must be complementary to passive systems to reduce their energy consumption, since these systems require a high energy consumption and have a negative environmental impact [45].

The dimension corresponding to the Passive design refers to those systems incorporated into the building, integrated from the initial conception of the design and that allow us to capture, control, store, distribute or emit natural energy contributions, without the intervention of any conventional energy source, in addition to the application to architectural design in order to make the most of what the environment offers us, and thus reduce our dependence on the facilities to achieve the desired comfort [46].

In this sense, with respect to the review of scientific studies, relevant contributions have been identified. This is the case of Rico [47], who carried out a study of sustainable architecture at an environmental and social level, corresponding to the countries of Italy, Spain, Bangladesh, West Africa and Mozambique. The sample was based on 7 completely sustainable projects, applying in each one an analysis of the contribution they make environmentally and socially. The results reflect that the new European regulations and subsidies have managed to transform architecture, leading us to socially aspire to durable, comfortable, intelligent and completely sustainable constructions.

Likewise, Torres et al. [48] conducted a study of sustainability compliance in a home in the historic center of Guanajuato, focusing on NOM 020 ENER regarding energy acceptance. The sample was taken under a non-experimental design and a mixed approach, which used statistics and documentary analysis to collect and structure the information. The results show a verification table of the sustainability aspects made up of 8 sections and 56 indicators. When applied to the house that was analyzed, it presents 27 sustainability characteristics and fails to comply with 29.

Cárdenas [49] carried out a specific study on the sustainable smart strategies that should be included in the object of study. The sample was taken in the central area of the National University of Engineering of Lima, specifically in the so-called Central Pavilion, and was developed using a qualitative, level and descriptive approach. The results in the field of innovation and design lead to improving the environmental quality of the building; understood by the standards given by the Faculty of Architecture of the UNI, and the technological character considering the incorporation of sustainable construction criteria by adding new materials or architecture that start from digital manufacturing.

On the other hand, Alfonso and Pardo [50] investigated the importance of sustainable technologies applied to architectural projects. The sample was taken in the city of Bogotá - Colombia, seeking to identify the relationship between sustainable technology and architectural project, using 3 methodological designs, descriptive, exploratory and synthesis and interpretation. The results led to the development of a series of theoretical notions, comprised in four important concepts: science, technology, technique and innovation, from these concepts it was possible to define and understand the context of application of said technology.

Galindo [51] conducted a study of sustainable architecture as an entity generated from its environment, as well as by the functional parameters implicit within the project theme. The methodology was developed under a qualitative approach, non-experimental design, whose sample was defined from 4 main concepts as part of the understanding of sustainable construction. The results show that certain methods can be applied within sustainable design, but never design formulas that generate predetermined responses, since each project has its particularities, and they can never be the same.

Malaver and Ortiz [52] analyzed the construction of sustainable buildings as an alternative for economic, social and environmental improvement. The sample was taken in Colombia, using as a method an analysis of secondary sources consisting of research theses, analysis of sustainable buildings and press articles. The results show the evident need for improvement in design and construction practices in buildings, which leads to the construction of sustainable buildings being totally energy efficient, being friendly to the environment and resulting in considerable economic savings.

Valero [53] conducted a study on the development of constructive design in sustainable architecture as a contribution to traditional architecture. The sample was supported by a qualitative approach, non-experimental design based on the application of documentary review of architectural design in the city of Valencia, Spain. The results show that the most important strategies that condition the design of sustainable architecture are protection and solar capture, natural ventilation, thermal insulation, thermal inertia and natural lighting, which will contribute not only to an eco-friendly environment, but also to quality and visual well-being, energy savings and light efficiency within the environments.

Di Bernardo et al. [54] studied the technological production in sustainable architecture to broaden the instrumentalist conception of technology. The sample was carried out using a qualitative method, analyzing texts that evoked the meanings and interactions involved in these processes. The results show the emergence of alternative and emerging approaches in the field of ASADES (Argentine Association of Renewable Energies and Environment) to transform the naturalized ways of generating knowledge about the production of new technologies in sustainable architecture.

Bautista and Loaiza [55] analyzed the characteristics of sustainable construction and traditional construction, to define the importance of the processes that must be carried out. The sample was made through secondary and tertiary bibliographic sources such as bulletins, articles on sustainable construction and traditional construction, considering the characteristics of each one. The results show that sustainable construction projects took on greater relevance because their construction system manages to generate less environmental impacts than traditional construction, in addition to considering the reincorporation or recycling of the materials used.

Tonato and Sinche [56] conducted a comparative analysis of three architectures and one reference model for IoT systems, offering a guideline for selecting the most suitable architecture based on specific needs and supported functionalities. The study employed a theoretical exploratory documentary analysis, in that sense information was gathered from academic databases focusing on publications from the last five years. Three widely recognized IoT architectures/ models- 3-layer, 5- layer and ITU Y.4000/2060 reference model- were selected for in depth analysis based on their prominence and explanatory depth. The results show that ITU Y.4000/2060 reference model emerged as the most comprehensive option offering management and security features. However, for business oriented IoT systems, the 5-layer architecture was more suitable due to its emphasis on system control and business integration.

Samaniego [57] analyzed sustainable development in Ecuador through the strategies used in the construction sector. The sample went through two stages of development: in the first, an exploratory-descriptive analysis was used and in the second, a one-story social interest housing type in the city of Guayaquil was analyzed. The results show that the two evaluation systems implemented did not classify the housing object of study, not even within the most basic categorization that they establish: despite achieving acceptable evaluations in socioeconomic and technical practices.

Rosero [58] studied the growth of “clean construction” processes in Colombia, focusing on sustainability as the main axis of this vital exercise in the creation of quality infrastructure and buildings. The sample is carried out through a descriptive process of the highlighted cases and then using the comparative method. The results show how this environmentally conscious exercise is firmly positioned in Colombia as a real alternative for contributing to sustainability and environmental conservation.

The literature on sustainable architecture reveals notable gaps in the integration of technological solutions with social and economic contexts, particularly in developing regions, where cultural and economic barriers limit their implementation. Furthermore, there is a lack of critical evaluation regarding the applicability of tools such as exergy in real-world projects, hindering the understanding of the practical challenges involved. The adoption of advanced technologies is also insufficiently analyzed in terms of its technical and financial obstacles, which prevents a comprehensive view of their feasibility within the sustainable construction sector, highlighting the need to emphasize the social purpose.

3. METHODOLOGY

This study was developed with a qualitative approach, using a documentary analysis under a non-experimental design. The research focuses on the analysis of three technical files of sustainable construction projects carried out in different geographical contexts: Australia, India and Italy. The selected projects are the Pixel Building in Australia, the Suzlon Building in Italy and the Suzlon Building in Italy. One Earth in India and Bosco Verticale in Italy, all recognized as benchmarks in sustainability practices. Each of these projects has achieved high levels of recognition in 2022, in part due to their commitment to LEED certification criteria, which positions them as examples of sustainable constructions in their respective urban environments.

The analysis unit of this study is determined by the LEED certification criteria that each of these projects meets. The LEED criteria were selected as a reference framework due to their wide acceptance and international recognition as a sustainability standard. For a project to be included in the analysis, it had to have obtained the maximum score in the sustainability criteria, thus ensuring that it meets the essential requirements to be considered a fully sustainable building with a social impact. Thus, the study exclusively covers projects that have maintained significant recognition at a global level during 2022, which guarantees their relevance and relevance in the context of sustainable construction. In contrast, those projects that did not comply with the sustainability regulations required to achieve LEED certification were excluded, as well as those that demonstrated limited or deficient use of sustainable resources, since these projects did not obtain recognition during the period studied.

The data collection technique used in this study was documentary analysis, for which a document review guide was applied as the main instrument. This guide was developed with the purpose of ensuring the collection of accurate and relevant information, focusing on the technical files of the three projects selected in 2022. The sources of information included official documents and databases, in addition to information obtained from official websites and other online resources about the Pixel Building, Suzlon One Earth and Bosco Verticale. Through this documentary analysis, it was ensured that the data collected were valid and applicable to the conceptual framework of the research, which in turn reinforces the reliability of the results obtained.

Data collection was carried out through a descriptive analysis, focused on identifying and highlighting those projects that achieved the highest ratings in LEED certification. In addition, the sustainable construction criteria that each country imposes on its projects were considered, thus allowing for the collection of data that are representative and specific to local policies and regulations regarding sustainability. This consideration of the regulatory contexts of each country adds a layer of depth and precision to the findings, providing a solid foundation for achieving the objectives proposed in the study.

Data analysis focused primarily on documentary analysis, which facilitated access to and a thorough review of key information from primary and secondary sources. This methodology allowed for the extraction and organization of relevant data, systematizing it to obtain detailed descriptions and meaningful content. Through this systematization, it was possible to identify common patterns and differences between the projects, providing a deep understanding of the sustainable strategies employed in each case. This meticulous organization of the data not only contributes to the rigor of the study, but also provides a solid basis for the comparison of sustainable practices between different projects and geographical contexts.

Regarding ethical considerations, rigorous measures were adopted to ensure integrity and accuracy in handling the data. Copyright and the integrity of the information sources were respected, avoiding any form of manipulation or misrepresentation. Furthermore, transparency in the presentation of results and veracity in the reporting of findings were prioritized, which contributes to the scientific and ethical rigor of the study. This ethical approach ensures that the findings presented can be used as a reliable reference for future research in the field of sustainable architecture.

4. RESULTS

Below are the results from the study carried out under a comparative method of architectural projects executed in Australia, India and Italy determined by The Pixel Building, Suzlon One Earth and Bosco Verticale, while identifying the architectural design under parameters of intelligent architecture, guaranteeing its sustainability from the active and passive designs proposed in this study.

Figure 1. Pixel Building in Australia
Note: The site of the former CUB Brewery has become the focal point of one of Melbourne's most ambitious and impactful development projects from Hosking and Gollings [59] [Photography].

The Pixel Building (Figure 1), designed by STUDIO 505 in 2010, is a pioneering eco-friendly structure in Melbourne, Australia. It is the first carbon-free office building in the country, featuring advanced water systems, renewable energy sources, and green roofs. The building achieves high energy efficiency through automation, solar panels, vertical-axis wind turbines, and natural ventilation. Its innovative façade integrates perimeter planters and shading blinds, creating a self-sustaining environment that reduces waste and energy consumption while promoting sustainability.

Figure 2. Suzlon One Earth Project in India
Note: A world - leading wind energy company whose design relied exclusively on non-toxic and recycled materials. Adapted from Ramprasad, [60] [Photography].

Suzlon Global Corporate Headquarters One Earth (Figure 2), built in 2009 and designed by Christopher Benninger, is one of India's greenest offices. Certified with Griha 5-star, it generates 8% of its annual energy through solar panels and windmills, making it a zero-energy project. The building's design integrates with its natural environment, utilizing natural light, cross ventilation, and a central water body for cooling and air quality improvement. Its open spaces capture exterior views, promoting interaction among staff, while recycled materials and a unique façade enhance its aesthetic appeal.

Figure 3. Bosco Verticale buildings in Italy
Note: Architectural approach that substitutes conventional urban surface materials with the dynamic polychromy of foliage for its walls from Rosselli and Cionci [61] [Photography].

The Bosco Verticale (Figure 3), located in Milan, Italy, was completed in 2014 by Boeri Studio. The two towers, 80 and 112 meters tall, house 480 trees, equivalent to 20,000 m² of forest. The project supports a habitat for birds and insects, contributing to urban biodiversity and ecosystem restoration. Its dense greenery creates a microclimate that absorbs CO_2, reduces noise pollution, and improves air quality. In 2015, it earned LEED GOLD certification and was named the most beautiful and innovative skyscraper by the Council on Tall Buildings and Urban Habitat, setting a global example for sustainable design.

In this sense, based on the theoretical description of the architectural projects, the study of the criteria proposed by the author on the Osma and Ordóñez model [44] is proposed, which leads to the study of both active and passive designs, highlighting how both models can be effectively integrated into contemporary architecture.

Table 1. Criteria for active design of architectural projects with social impact: Pixel Building – Australia, Suzlon One Earth – India, Vertical Woods – Italy

Elements	Description
Renewable energy	These buildings generate their own energy through renewable sources like solar panels and wind turbines. This promotes community resilience by reducing energy dependency and fostering sustainability, which benefits local populations by offering cleaner, more reliable energy sources.
Water collection and reuse system	The integration of water reuse strategies, such as purifying river water and recycling wastewater for heating and irrigation, ensures a sustainable water supply. This reduces the strain on local water resources, helping to ensure equitable access to water for the community, especially in areas facing scarcity.
Air conditioning system	Efficient air conditioning systems optimize energy use, which not only lowers environmental impact but also creates healthier living environments. These systems improve the quality of life for residents by maintaining comfortable indoor temperatures and air quality, essential for their well-being.

Note: Development of active design criteria, proposed by renewable energies, collection systems, water reuse and air conditioning system based on the model developed by Osma and Ordoñez [44].

In accordance with Table 1, it is evident that the active criterion, the adoption of clean technologies and renewable energy, not only contributes to the reduction of environmental impact but also promotes a cultural shift towards sustainability, inspiring society to adopt more responsible consumption habits. These buildings, by demonstrating that the integration of innovative technologies can be economically viable, serve as examples of how communities can reduce their dependence on polluting energy sources, thus improving collective well-being. In addition, these initiatives encourage the creation of green jobs, offering new employment opportunities in sectors related to sustainable construction and resource management, which reinforces social equity by generating employment in areas of high social impact.

In accordance with Table 2, it is evident that the passive design focuses on observing the natural resources of the environment to achieve ideal thermal regulation, and identifies criteria for lighting and ventilation, ensuring reductions in dependence on mechanical systems and energy consumption. In this sense, by reducing reliance on artificial systems, passive design not only promotes environmental sustainability but also creates comfortable and healthy spaces for its occupants, integrating harmony with its surroundings and fostering lasting social well-being. This strategy allows for the creation of environments that support the health and quality of life of individuals while respecting and adapting to the natural context around them.

Table 2. Criteria for passive design of architectural projects with social impact: Pixel Building – Australia, Suzlon One Earth – India, Vertical Woods – Italy

Elements	Description
Recycled materials	The use of recycled materials in construction not only reduces environmental impact but also promotes a circular economy in communities. This creates a healthier and more accessible environment for residents, while raising social awareness about the importance of reusing and reducing waste.
Lighting and natural shading	Utilizing natural light and ventilation to illuminate and ventilate spaces not only reduces energy consumption but also enhances the health and well-being of residents. This approach contributes to creating healthier environments, promoting a better quality of life by providing direct access to natural light, which improves mood and productivity.
Natural ventilation	The integration of natural ventilation systems reduces the need for artificial cooling, decreasing energy costs and fostering a fresher, healthier environment. This approach not only creates more pleasant living spaces but also allows for greater connection to the natural surroundings, enhancing social integration and overall well-being within the community.

Note: Development of passive design criteria, proposed by recycled materials, lighting, natural shade and natural ventilation, with respect to the model developed by Osma and Ordoñez [44].

5. DISCUSSION

It was determined that sustainable intelligent design achieves the development of projects that more decisively associate natural resources and their contribution within projects with social impact, thereby achieving that, within the architectural process, sustainability has a primary focus, before executing the design of any project. Besides, in accordance with Tables 3-5, which evaluate the effectiveness, costs, and social benefits, the results obtained show that the adoption of intelligent and sustainable architecture approaches in projects such as Pixel Building, Suzlon One Earth, and Bosco Verticale have enabled not only the successful integration of renewable technologies, such as solar panels and water collection systems, but also the use of passive solutions, such as natural ventilation and energy efficiency, with a positive impact on the people who make use of the buildings. These projects demonstrate that it is possible to reduce environmental impact, generate more comfortable environments and contribute positively to society, creating spaces that promote biodiversity, improve air quality, and minimize resource consumption. The implementation of renewable energy and recycled materials has been fundamental to achieving high levels of sustainability certification, such as LEED, positioning these buildings as role models for future urban developments.

Table 3. Evaluation of effectiveness, costs and social benefits based on active and passive criteria in Pixel Building

Elements	Pixel Building
Effectiveness	It achieves carbon neutrality, generates more energy than it consumes, and maintains a balance in water usage. It employs renewable energy sources and sustainable materials, significantly reducing its carbon footprint. Its contribution to the community is key, as it fosters energy autonomy, reduces dependency on external sources, and promotes a cleaner and more sustainable urban environment.
Costs	The initial investment in eco-friendly technologies and materials is high, but it pays off with long-term savings and energy efficiency. While significant, the upfront cost is offset by long-term reductions in energy costs, making similar future projects more viable. This also benefits the community by contributing to long-term sustainability.
Benefits	Energy self-sufficiency and efficient water management ensure that the building is not only sustainable but also serves as a model for other constructions. This building promotes the use of clean technologies, reducing environmental impact and improving quality of life in the city, encouraging a more sustainable urban development model that benefits the entire community.

The results obtained demonstrate that the adoption of sustainable architectural principles, such as the use of natural lighting and cross ventilation, effectively complements renewable technologies, favoring greater energy autonomy and reducing the use of conventional resources. These elements not only optimize the energy performance of buildings, but also generate a positive impact on cities, by promoting biodiversity and improving air quality. This type of project shows how the integration of innovative solutions can contribute to creating a healthier urban environment and highlights the importance of buildings of the future responding not only to environmental needs, but also to a clear social purpose. Furthermore, these architectural models serve as a reference for future constructions, demonstrating that it is possible to align technological innovation with respect for the environment and social well-being, promoting sustainable development in projects of different scales.

Table 4. Evaluation of effectiveness, costs and social benefits based on active and passive criteria in Suzlon One Earth

Elements	Suzlon One Earth
Effectiveness	It implements an efficient design that optimizes energy usage, harnesses renewable energy, and conserves water, reducing dependence on fossil fuels. It provides an efficient and healthy environment for employees, contributing to a more resilient community by promoting sustainable practices.
Costs	The considerable investment in green infrastructure and renewable energy technologies comes with high initial costs, but the long-term benefits, such as a reduced carbon footprint and improved urban quality, create value for society by reducing future expenses and improving the surrounding environment.
Benefits	The use of renewable energy and water conservation measures improve the building's energy efficiency, while recycling and waste reduction strategies contribute to the sustainability of the surrounding area. The building promotes a healthier environment, lowers operational costs, and creates a sustainable working space.

Table 5. Evaluation of effectiveness, costs and social benefits based on active and passive criteria in Vertical Woods

Elements	Suzlon One Earth
Effectiveness	It maximizes energy efficiency using renewable energy and natural light, while also promoting biodiversity in the city with its green facades. The building improves air quality and provides a healthier living space, integrating nature into a dense urban environment, benefiting residents by offering a more sustainable environment.
Costs	The integration of innovative technologies such as the smart irrigation system and wind turbines requires a significant investment. However, these costs contribute to the creation of a eco-friendlier and healthier environment, with long-term benefits such as improved biodiversity, reduced pollution, and the development of more livable spaces.
Benefits	The integration of an ecosystem in the building's facades improves biodiversity, while reducing pollution and using renewable energy to decrease the carbon footprint. The building's design contributes to creating a more livable space that mitigates urban heat island effects and improves air quality, providing a healthier living environment for residents and the broader community.

The studied projects, based on the dimensions of active and passive design, coincide with the guidelines considered in the analysis, confirming that a sustainable and intelligent design is essential to achieve comfort and sustainability in architecture. According to the results of Rico's study [47], these projects show that the fundamental characteristics of an efficient design are achieved through the appropriate use of renewable energy, recycled materials and natural systems such as natural lighting and ventilation, elements that contribute not only to energy efficiency but also to the environmental and social transformation of architecture.

By analyzing the active and passive dimensions, the results of Torres et al. [48] confirm that the projects studied meet the requirements to be considered sustainable, highlighting the use of renewable energy as a key aspect for the development of future buildings. These findings underline the importance of the integration of renewable technologies and natural resources, allowing an evolution towards more environmentally responsible constructions.

Within passive design, the use of recyclable materials and new materials derived from digital manufacturing, as Cárdenas [49] emphasizes, represents a key direction for sustainability. This not only improves environmental quality, but also promotes innovation from an ecological perspective, positioning the use of sustainable materials as a fundamental pillar for the future of architecture.

On the other hand, guidelines on innovative techniques and technology in passive design have been crucial for the analyzed projects, which implemented natural lighting and ventilation strategies. The results of Bustamante-Gonzales et al. [12] highlight the relevance of understanding the context of application of these technologies, which allows a significant development in architectural design and an advance in the use of science, technology, and innovation within sustainable architecture.

The results derived from Galindo's study [51] show that, although the projects comply with various concepts for sustainable construction, each one has characteristics that respond to its specific needs. This variability highlights how the particularities of each project contribute independently to the achievement of an architecture that is not only sustainable but also has a positive social impact.

Likewise, the importance of the active and passive dimensions in sustainability is validated by Tonato and Sinche [56], who state that these characteristics are essential for projects to be recognized as sustainable, providing both environmental and economic benefits. These findings highlight the need to integrate both technological and natural solutions to achieve efficient constructions with less environmental impact.

In turn, these dimensions form an integral system within the sustainable construction approach. As Valero [53] points out, strategies such as solar capture, natural ventilation, and natural lighting not only improve energy efficiency, but also contribute to the quality of the indoor environment, creating healthier and more pleasant spaces for their occupants. Furthermore, these dimensions pave the way to explore new technological alternatives in the production of sustainable buildings. Di Bernardo et al. [54] highlight the emergence of new technologies that could further improve sustainability in construction, reducing costs and development times, reflecting a move towards more efficient and accessible architecture.

Finally, the construction process that follows active and passive design standards is a challenge due to the lack of features in many current construction methods to achieve sustainability. However, Bautista and Loaiza [55] show that sustainable constructions generate lower environmental impacts and make more efficient use of resources, which positions them as a viable alternative to traditional constructions.

The analysis of technologies within the dimension of active design reveals the importance of technological innovations, which are considered essential for smart and sustainable design. According to Tonato and Sinche [56], the implementation of electronic devices powered by renewable energy, such as solar or wind, is essential to promote the development of more dynamic spaces adapted to the needs of the environment, standing out as a key trend for buildings of the future.

Therefore, although the implementation of active and passive strategies in the studied projects requires a considerable initial investment, the long-term benefits far outweigh the costs. The integration of renewable technologies, such as solar panels and water collection systems, combined with passive solutions like natural ventilation and efficient lighting, optimizes resource use and significantly reduces conventional energy consumption. This not only improves energy efficiency but also lowers operational costs over time, contributing to greater autonomy and sustainability. Additionally, social benefits such as improved air quality and the creation of healthier spaces justify the investment, demonstrating that sustainability in construction is a profitable investment for both the environment and communities. Thus, these strategies establish themselves as an effective and efficient option for the architectural design of the future.

This study has certain limitations, firstly, taking as a reference iconic building that exemplify the broad spectrum of sustainability and the ideal objective to pursue. However, within future research, it is important to consider the execution of sustainable construction practices by evaluating the status of construction projects in developing countries, such as the Latin American region. This region is affected by climate change and urban growth, so the expansion of cities demands a massive impact on the environment, and thus ensures the well-being of the inhabitants, reducing elements of interior pollution and excessive use of energy.

6. CONCLUSIONS

This research aims to assess the social impact of adopting smart architecture in the design of sustainable buildings. Sustainability achieved through smart design allows construction projects to promote effective development without compromising the environment, taking advantage of natural resources in a beneficial way. It is concluded that active design, which includes the use of renewable energies such as solar and wind, as well as the implementation of energy-efficient equipment, constitutes a solid basis for considering a project as truly sustainable. This approach not only optimizes energy consumption, but also reduces dependence on conventional resources, aligning architectural design with the principles of sustainability.

Passive design, on the other hand, integrates systems that maximize the use of natural conditions in the environment, such as natural lighting and cross ventilation, which contributes to the reduction of conventional energy consumption with minimal environmental impact. The combination of active and passive strategies offers a comprehensive solution that preserves natural resources and promotes greater social awareness of the importance of sustainability in construction. Future projects are encouraged to incorporate these approaches from the earliest stages of their design, to optimize both energy efficiency and the quality of life of communities, generating a healthier environment and contributing to sustainable and equitable urban development.

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