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ENVIRONMENTAL CERTIFICATIONS IN BUILDINGS
How sustainable are green buildings?

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ABSTRACT
Over the last decade, urban growth in Peru has been high, leading to a renewal of the face of cities. This process is complex due to two issues, the expansion of cities and the renovation of old blocks. The first case verifies the presence in the city of different buildings with sophisticated technological applications (smart building) and the second case the control of energy and water consumption (green building). The research described the use of the database of registered projects and buildings underlying the GBC (2013-2018), using statistical analysis tools that determined patterns and trends, in terms of credits completed or met according to LEED categories. Finally, it analyzed energy, water, and other criteria that influence sustainability through MCA (multi-criteria analysis) using a double MAS type input. Green buildings contribute to environmental sustainability through site selection, use of tools to reduce energy consumption, and features that promote low emissions. They contribute less in terms of social sustainability, compared to other certifications such as BREEAM. Core and shell, New construction or Existing building are registered under the 'low carbon' and 'carbon neutral' initiatives, mostly satisfying the aspects addressed in the 'energy & atmosphere' criterion. However, they have a low match in eco-efficiency issues, especially with respect to water.

KEYWORDS
green buildings, LEED, environmental sustainability, ecoefficiency, sustainable development

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The strong growth of the construction sector in developed and emerging countries has not only affected its economic growth, or the welfare of the inhabitants, it has also had effects on the level of environmental impact, causing more waste, significant increases in energy consumption, water and raw materials (such as steel and iron). In Table 1, we can see how the latter raises concern of scientific measures and pressures to environmental load, and in the area of construction, a wide range of environmental certifications (Quesada, 2014). It is also considered a more important goal directed at increasing sustainability in structural designs (Pongiglione and Calderini, 2016). Nowadays, ecofriendly construction considers ecological effectiveness as an essential condition or value in modern building construction process, i.e., aimed at obtaining not only environmental certifications, but above all, ensuring environmental sustainability based on the qualitative characteristics of buildings and surrounding areas (Mkrtchyan and Lokhova, 2017).

Such certifications diversity can be grouped into three types. The first, includes methodologies that tend to appreciate performance with the credit system, such as LEED and BREEAM Macias and Navarro (2010). The second is related to eco-efficiency input/output ratios, as in the case of the CASBEE method, which analyzes the results of the construction process in terms of the value of the product or service per unit of environmental burdens. Finally, are nested matching tools such as GBTool, employing hierarchical trees, which distinguished areas, categories and criteria. These authors also refer to the methodology proposed by ISO (ISO/TC 59/SC – Sustainability in Building Construction), which is based on the green methodology, a new building certification method (Cornejo Cárdenas, 2017).

There is a vast literature on sustainability from a theoretical perspective (Pearce and Atkinson, 1993; Allenby, 2012; Sachs, 2015). An option to determine the environmental sustainability of buildings is through life cycle analysis (García-Torres, Kahhat and Santa-Cruz, 2017; Huedo and López-Mesa, 2013). Another option is the use of the systemic sustainability array (MSS), as well as as those that obtain the analysis observations with multicriteria environmental performance indicators – MCA (Cornejo Cárdenas, 2017; Castillo Haeger and del Castillo Oyarrzún, 2015). Similar variants have been developed on environmental assessments for the construction as vectors of analysis process: sustainable construction criteria and management of safety criteria applied to housing as in the case of housing of Mexico (Ramos et alii, 2016).

Certificates as for example, projects with LEED are based on aspects such as climate and quality of the construction environment, techniques and materials for construction and control of environmental burdens (energy, water, light and thermal comfort), benefiting the environment and, at the same time, with an increase in the cost of the initial investments. However, there are several cases that refer to important and interesting rates of return for this type of projects (Ribero et alii, 2016). In Table 2, advances in sustainability assurance, for different methodologies, have made it possible to extend the practice of individual certification into larger buildings or dwellings,

Organizations	Methodology
BRE (Building Research Establishment)	BREEAM Multi-Residential
USGBC (U.S. Green Building Council)	LEED-Home
GBCe (Green Building Coucil Spain)	GREEN New Edification: Residential and Offices
JaGBC (Japan Green Build Council) JSBC (Japan Sustainable Building Consortium)	CASBEE for New Construction
Association QUALITEL	Quality Habitat & Environement

	LEED ND (2009)	BREEAM (2012)	GS COMMUNITIES
COMPONENT	Smart Location and Networks (25%)	Governance (9%)	Governance (19%)
	Neighbourhood Patters and Design (40%)	Social/Economic Well-being (42%)	Design (9%)
	Green Infrastructure and Buildings (26%)	Resources and Energy (22%)	Habitability (16%)
	Innovation and Design Process (5%)	Land use and Ecology (13%)	Economic prosperity (18%)
	Regional Priority (4%)	Transport and Mobility (14%)	Environment (28%)
			Innovation (9%)
CERTIFICATION	110 points	100 points	110 points
	+80 (platinium)	+70% excelence	75% world leader

Table 1 | Types of certifications or seals green buildings according to their origin – Organization (based on Quesada, 2014).

Table 2 | Environmental Certifications for sustainable neighborhoods (based on Blanco, 2016).

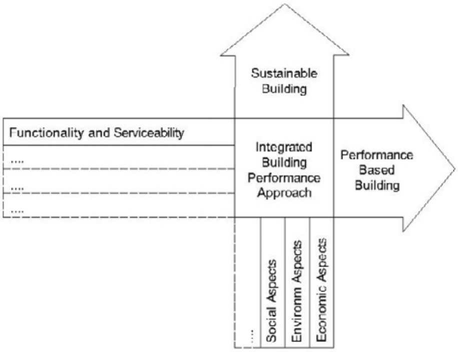
such as a complex of buildings, and even neighborhoods set (Blanco, 2016). That is the case with LEED ND (2009) and BREEAM Communities (2012) or Green Star Communities (2012-2015) certifications.

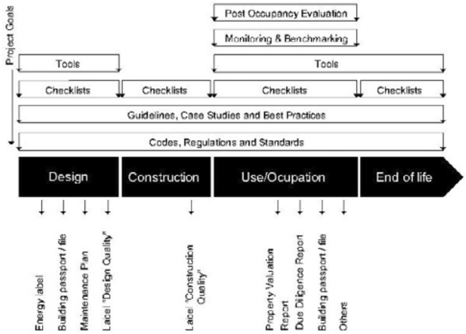
The question is whether such programs will effectively and efficiently control environmental loads and pressures and thus contribute to environmental sustainability.

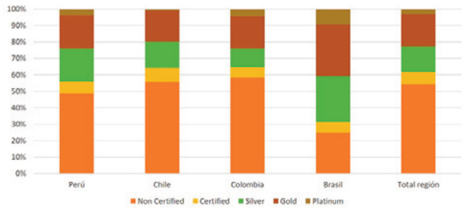
Several criticisms have poured into certifications suggesting that it is better to make decisions based on quantitative assessment systems, as it is the case with life cycle analysis (LCA) and life cycle cost (LCC) analysis (Lützkendorf, 2010) that have postulated a synthesis of sustainable and eco-efficiency buildings. In both cases, there are supporters and detractors; both highlight the importance of further research in this field of knowledge (Fig. 1). In this sense, is important to mention the urban growth of the past decade, which has renewed the face of cities, for example Lima is the one that has most changed, also Trujillo in the North, and Arequipa in the South. This process is not only the expansion of cities into new lands, it is what urban planners named as 'urban erosion' referring to the change in land use. This process has also led to the renewal of old houses and entire neighborhoods, where today we find buildings up to 30 and 40 levels (considering basements and upper levels). Many of them emerged thanks to sophisticated technological applications, giving rise to smart building; others seek to control the energy and water consumption as the green building. Like many environmental certifications such as ISO 14000, LEED has experienced a significant growth in different regions of the world. In Latin America, LEED has had an important development in Mexico with more than 2000 projects, followed by Chile with 407, Colombia with 300, and a Brazil with 32 projects (GBC, 2018), and in this trend, Peru did not make a difference, registering 154 projects (Fig. 2).

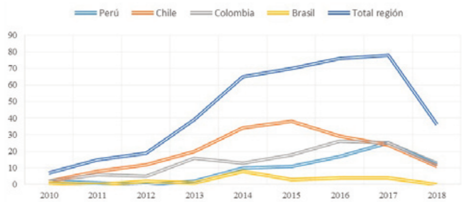
The growth trend, typical of this type of environmental certification collected by the ISO 14000 family as green stamps, occurs at different speeds. We observe that in Chile and Colombia they have higher speeds than those recorded by Peru or Brazil. At the regional level, the trend is growing, however, Chile and Colombia have entered in a downward cycle probably due to other new certifications, which make the interest to achieve a certification LEED decay over time. In this regional context, Peru's case is qualitatively different for two reasons. First, the growth curve shows a more toned-down slope for the first years of the time series (Fig. 3), acquiring rapid growth in the period 2014-2017. It is possible that, in the medium term, the trend is still maintained in terms of growth and resilience, this thanks to the decision of the national Government to promote sustainable buildings with attractive loans for 'techo propio' (own roof) type houses.

The present study has a theoretical intended to establish the levels of real and technically reliable sustainability of green building. In another way, the high initial costs have positive rates of return in the medium to long term, suggesting that it is a sustainable investment for the environment and for the economy also. In another way, the studies explore the conceptual perspective developed theory by Allenby works (2012) regarding the limitations of technology in environmental sustainability, as well the theoretical prospect of the economy (Pearce and Atkinson, 1993; Sachs, 2015), leading to a discussion of whether or not the technology available today warrants long-term environmental sustainability. In this context, the study developed aims to determine the environmental sustainability of buildings built with LEED green certifica-









LEED Certification					
Sustainable sites (SS)	Water Efficency (WE)	Energy and Atmosfere (EA)	Materials and Resourses (MR)	Indoor Environmental Quality(IEQ)	+ (aditional Category) Innovation in Design (ID)

Fig. 1 | Integration of philosophy of sustainable building and eco-efficiency by Lützkendorf (2010).

Fig. 2 | Certifications granted by LEED levels according to countries (based on usgbc.org).

Fig. 3 | Certification paths LEED according to countries for the period 2010-2018 (based on usgbc.org).

Fig. 4 | Categories deemed certification LEED applicable to various types of constructions – GBC 2018.

tions, referring to the impacts in the environment. For this purpose, it is necessary, first, to estimate using multi analysis, green building environmental sustainability certified with LEED. Secondly, identify the most used strategies by the eco-design to achieve environmental certifications, and finally, to assess the impacts on the environment arising from the green building certified with LEED.

It should be noted, that LEED considers four progressive levels of certification, based on 100 points, in addition to 6 points for design innovation and 4 points in Regional priority. A building is categorized as 'certified' if it achieves 40-49 points, 'silver' if is certified with 50-59 points, 'gold' if gets 60-79 points, and 'platinum' if scores 80 points or more. The project will use the database to record projects and certifications granted by Green Building Consul-Peru through December 31, 2018 (Fig. 4). The collected information is related to the evaluation criteria, recorded in the scorecards of the projects, and are available from the new.usgbc.org/ website. This database showed the credits obtained by the project, in their different categories: energy, water, design, environment, among others, which determined the environmental impacts in terms of water and energy consumption with the help of the environmental matrix of the MSS type, using the MCA tool (Tab. 3). The procedure used in the research believes to a development by stages, is shown in the Figure 5. To ensure the representativeness of the study, a procedure shows under simple random sampling (SRS) considerations, which considered the following expression, where $D = B^2/4$ and at the error limit of the estimate of the proportion of loans affecting sustainability with respect to the total of credits.

$$n = \frac{Npq}{(N-1)D + pq}$$

$$B = 2\sqrt{V(\rho)} = 2\sqrt{\frac{pq}{n-1}\left(\frac{N-n}{N}\right)}$$

Applying the expression to estimate the sample size is 3.69≈4 for each of the main building types. Since its inception, LEED certification has been a benchmark for the design and construction of smart, environmentally friendly, high-performance buildings. This considers certification of an important variety of buildings, ranging from new construction and renovations, existing buildings, commercial interiors (structure and facade), schools, health centers, commercial establishments, and neighborhood development. According to the GBC, to date there are more than 418 thousand sqm, and pretends to have an impact on very specific aspects of sustainable construction. In this context, green certifications in the national market are increasing and the trend is still the same until the end of the decade. Certificate applications show us precisely this trend from two perspectives. The first from higher LEED certified buildings and another from the wide range of building types they require, that detail can be seen in Figure 6, shows that 40% of certifications and/or requests are concentrated in the Core and Shell type, followed by New Construction with 24%, and Existing Buildings with 12%. This distribution is not coincidental, and relates to the trends experienced by the construction sector, focused on new buildings and large scale remodeling of pre-existing buildings.

Figure 7 illustrates the relationship among buildings with certifications and buildings without certification. Success rates are high (0.48), in the areas of Commercial Interiors, Healthcare and Retail-Commercial Interiors. They are lower in the Core and Shell and Existing Buildings types. This means the relatively complex interventions such as the Healthcare and Retail-commercial Interiors have for their design and technical requirements, greater probability of achieving certifications. On the other hand, buildings with less complexities, with less demanding design and less technical requirements have a lower probability of success (Fig. 8).

Dimension or Parameter	No consider	Encasement	Fairly	Outstanding	Fullfillment	Value
Enviromental Sustainability						
Land use						
Water						
Air						
Energy						
Ecology						
Social Sustainability						
Cohesion						
Mobility						
Economy Sustainability						
Connectivity						
Efficiency						

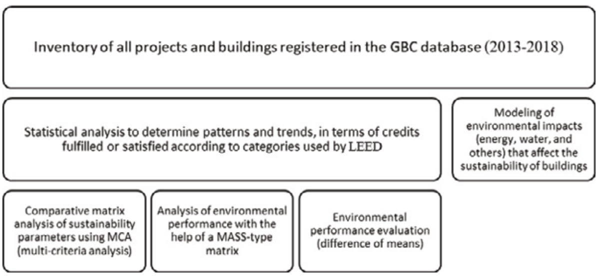
Tab. 3 | Matrix of the array of systemic sustainability (based on Cornejo Cárdenas, 2017).

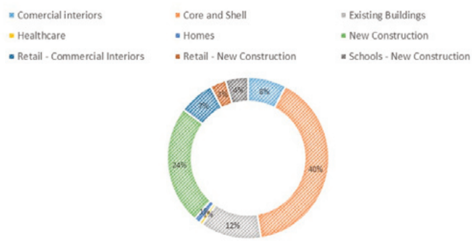
Strategies identified in green certification: A look from the designers and real estate management | What are the strategies followed by real estate operators in the field of LEED-type environmental certifications? Is it therefore true that the greater the complexity, the more successful the certification? These are some questions that are important to answer in order to describe the behavior of agents in the Green Buildings market. Table 4 presents the compliance level of the maximum payable credits for each category or criteria of LEED certification, according to which there are important differences between building types, mentioning that Commercial Interiors, Core and Shell, and Existing Buildings have the greatest number of criteria satisfied in its entirety. The buildings with lower levels of compliance are New Construction, Retail-New Construction and Schools-New Construction.

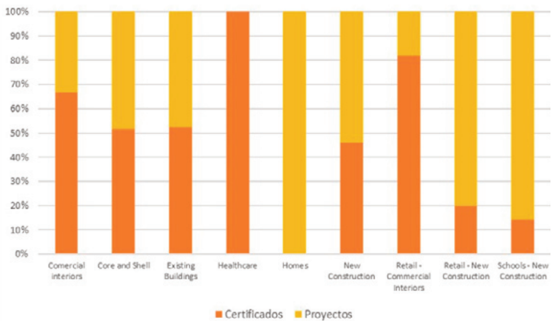
By the compliance levels, the Sustainable Sites [SS], Water Efficiency [WE], Innovation [ID] and Regional Priority [RP] criteria have the highest average, ranging from 0.73 to 0.96. differences are seen in Energy & Atmosphere [EA], Material & Resource

[MR] and Indoor Environmental Quality [IEQ] criteria. The coefficient of variation, shows the relationship between the standard deviation and the arithmetic mean, which shows high levels of dispersion for the EA and MR IEQ criteria, and less dispersion in RC, SS, and WE. Based on the last paragraph, one might think that operators tend to focus their efforts on location selection and design techniques to make it environmentally friendly, to improve water consumption efficiency, design innovations, and regional credits. Only two aim for a real rate of contribution of the environmental sustainability of the building. Energy efficiency is important in the context of climate change, as is finding more sustainable materials and resources, which decreases consumer pressure about the ecological footprint on the planet.

Towards a sustainability model | Sustainability can be seen from various perspectives. One of these is to consider the technical, social, and economic measures that affect the well-being of the individual. On the selected sample of LEED-certified buildings, demonstrated different approaches that have different levels of incidence and make dif-







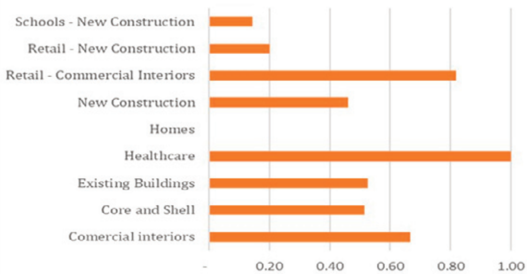


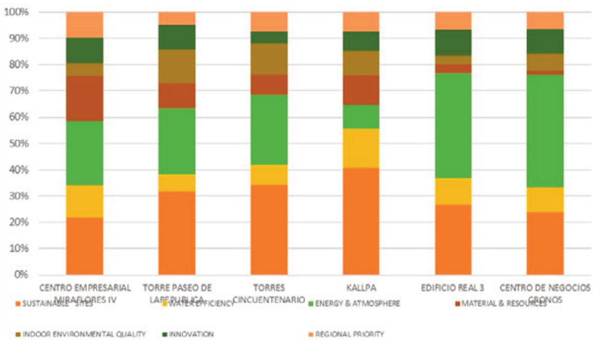
Fig. 5 | Detail of the methodological path developed in research.

Fig. 6 | Distribution of buildings (including projects in process or archived) according to types of intervention LEED.

Fig. 7 | Applications for certification according to State by types of buildings LEED, includes projects in process or archived (based on GBC, 2018).

Fig. 8 | Rate of success according to type of building LEED.

Types of Building	Sustainable Sites (SS)	Water Efficiency (WE)	Energy and Atmosphere (EA)	Material and Resources (MR)	Indoor Environmental Quality (IEQ)	Innovation and Design (ID)	Regional Priority (RP)
Commercial Interiors	1	0.55	0.68	0.29	0.25	1	1
Core and Shell	0.93	1	0.54	0.46	0.53	1	1
Existing Buildings	0.62	0.57	0.63	0.2	0.13	1	1
Healthcare	0.5	0.56	0.26	0.44	0.08	0.67	1
New Construction	0.92	0.8	0.17	0.43	0.45	1	0.75
Retail — New Construction	0.71	0.73	0.35	0.07	0.29	0.33	1
Schools — New Construction	0.88	0.91	0.7	0.31	0.5	1	1



Tab. 4 | Compliance level of credits according to criteria or categories of certification LEED.

Fig. 9 | Levels of importance of the criteria fulfilled in obtaining a certification LEED to a group of buildings.

ferent comments. For example, the criteria of Sustainable Sites affects between 20% and 30% of the achieved credits, the Water Efficiency criteria have extreme relevance to the sustainability, only affects 7-15% of appropriations made in the certification. A better performance can be seen in the Energy & Atmosphere category that explains between 9% and 43% of the credits achieved in the certification process (Figg. 9-11).

Sustainability theory should not be ignored, special care should be taken for the issue of resource consumption, where material recycling practices, use of renewable resources with sustainable extraction are important, also performance improvement in the use of such resources (eco-efficiency practices). The item of Material & Resources has a low importance to obtain credits, and extends the range of 2 to 17%, that makes it practically in a marginal criterion. Cities, buildings tend to incorporate important structural elements in favor of insulation; therefore, LEED certification considers a special indoor space environmental quality standard. This criterion will have between 3 and 13 p%. Finally, the innovation criteria and regional priorities. In the first (innovation) has a range of 4 to 10% of the allocations, and the regional priority criterion shows a ratio of 5 to 10%. Following the methodological considerations exposed by Cornejo Cárdenas (2017) a comparative table with the results of the environmental matrix MASS, with the use of the MCA evaluation was made, can be seen below. The results presented in Table 5 for LEED performance in all types of environmental construction are high and represent 53 and 63% of total sustainability.

Performance in economic sustainability represents 25% of total sustainability. Social sustainability constitutes, for the analyzed cases, between 13% and 20%. The differences in environmental sustainability are significant between Core and Shell and other building types, while in social sustainability between New Construction and other certifications. In terms of economic sustainability, lastly, the differences between Core and Shell compared to other building types are given. Around green buildings there are various interpretations related to sustainability, many are unfair and exaggerated evaluations insofar as they attempt to extend the macro of the sustainability assessment to the building and within it to a particular element (a building), which continues to be an aspect in the micro scale of sustainability (Lützkendorf, 2010; Macias and García-Navarro, 2010). The question should not be generalized, whether green buildings are or are not sustainable, since such an assessment would be performance in the economic sphere to measure the effects of the decision to invest in the construction of a sustainable building to contribute to national GDP or GDP per capita.

In this perspective, the cost of the investment and its impact on the long-term growth prospects of the sector have also been considered (Wan, Liu and Lai, 2017). One should not only focus on assessing the environmental impacts on the social environment, and from the triple bottom line perspective (Huedo and López-Mesa, 2013; Quesada, 2014; Dias-Angeloa, Jabbourb and Calderaroc, 2014) analyze its effect on social sustainability, measured as access to housing, services, and or improvement of assets as a result of lower placelessness (Castillo Haeger and del Castillo Oyarrzún, 2015). Recently, sustainable approaches have extended to hotel management and the design of tourist complexes, while environmental aspects cover energy, water, material resources, and the effectiveness of solid waste management (de Oliveira Menezes and Kindl da Cunha, 2016). These issues receive less interest from real estate agents and designers, as indicated by our results, and agree with the theoretical considerations exposed by the author of Structural Sustainable Design (Pongiglione and Calderini, 2016).

In this context, the proposed study approaches the microscale of sustainability and the behavior of typical cases to draw conclusions with respect to three aspects of interest. The first one is related to the behavior of buildings on the three areas of sustainability (economic, social and environmental) also in a qualitative way to estimate their performance.

Fig. 10 | Cronos-Bussiness Center – Certification level: Gold-2017 (credit: usgbc.org).

Fig. 11 | Torre Cincuentenario – Certification level: Gold (credit: ulima.edu.pe).

The second, would involve a debate on the contribution of green buildings in the area of eco-efficiency, especially in energy and water policies, and jointly the implementation of low carbon policies or carbon neutral philosophy (Wan, Liu and Lai, 2017). Lastly, the efforts, of the entrepreneur or the head of the household, should be

Dimension/Parameter	Building types		
	Core and shell	New construction	Existing building
Environmental Sustainability	**10**	**16**	**15**
Land use	2	4	2
Water	2	4	3
Air	2	2	4
Energy	2	2	4
Ecology	2	4	2
Social Sustainability	**2**	**6**	**3**
Cohesion	1	3	1
Mobility	1	3	2
Economy Sustainability	**4**	**8**	**6**
Connectivity	2	4	3
Efficiency	2	4	3

Tab. 5 | Performance of buildings LEED according to the model of triple sustainability (economic, environmental and social) by types of buildings.

evaluated from the perspective of supporting their nation to comply with the Paris-2015 agreements (Ribero et alii, 2016).

It shows that green buildings certified by the LEED platform, contribute significantly to environmental sustainability, due to the choice of sites, the use of mechanisms for reducing energy used and other aspects that promoted the reduction of emissions. However, they contribute less in terms of social sustainability, as LEED criteria focus more on buildings than on the surrounding environmental impact, unlike other certifications such as BREEAM. Buildings, Core and shell, New Construction, or Existing Buildings fit within the framework of 'low carbon' and 'carbon neutral' initiatives, and largely meet Energy & Atmosphere requirements, although they make little contribution in terms of eco-efficiency, especially in the water issue. Finally, the fringe value of criteria such as Material & Resources and Indoor Environmental Quality means that government building may be in favor of green buildings, likely discouraged by other low-cost initiatives (Mi Vivienda Verde – My Green Home). This is because the state, on the issue of sustainability, prefers an alternative system to a certification of an established system, which is more expensive or low cost-benefit.

About the green building perspective, several items must be considered, for example, integrated the management risk in the building life cycle, means, incorporate a new category addressed to control of environmental risk, focusing on the control of fire and its emissions, with LCA or EIA tools (Martin, Tomida and Meacham, 2016). The main purpose is to determine the environmental sustainability of buildings constructed with LEED green certifications, in terms of environmental impact, it is concluded that buildings contribute significantly to environmental sustainability and to a lesser extent to economic and social sustainability. The highest cost of green buildings is an average of 35%, more per square meter.

About the strategies used by designers to achieve environmental certifications, it has been determined that investors and developers of projects certified with LEED tend to give priority to the Energy and Atmosphere criteria followed by the Sustainable Site criteria and the fulfillment of Regional Priority, all of which have high levels of Innovation. Difference strategies depending on the building type, building proponents are closer to New Construction or Existing Building than those who favor Core and Shell building. Multi-Criteria Analysis (MCA) has been useful, not only to determine the level of environmental sustainability of green building certified with LEED, also because it has allowed to assess the impacts of the satisfied criteria in the care of the environment that generate these, concluding that more complex buildings have major environmental impacts than simpler interventions. Therefore, given the significant positive effects on the land related to the choice of the project site and the decrease in water consumption (energy eco-efficiency) and lower emissions of pollutants (low emission). Under this aspect, we can also appreciate considerable differences between the three types of buildings studied.

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