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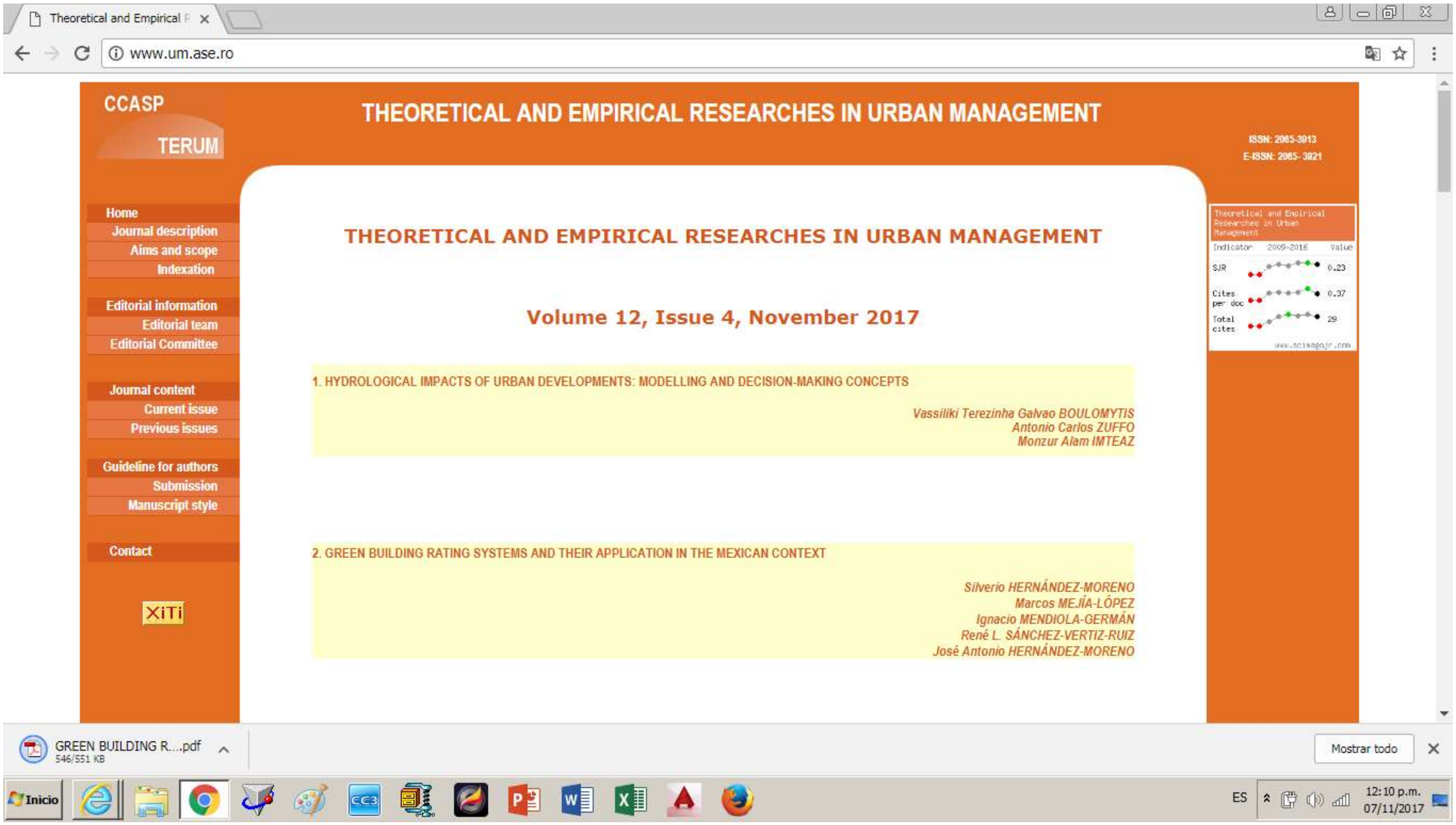

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GREEN BUILDING RATING SYSTEMS AND THEIR APPLICATION IN THE MEXICAN CONTEXT

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Abstract
This article offers a review of the scientific literature aimed at putting forward a proposal on the main variables or categories of sustainable design to take into consideration to manage, plan, design, build and maintain buildings in Mexico. The methodology consisted in reviewing 5 successfully tried international green building models (rating systems), from which a series of requirements by sustainable category were taken in order to propose categories and variables proper to the Mexican context. The result was a checklist that comprises sustainable design requirements broken down by categories: natural, human, technologic and economic to apply in the Mexican context. It is concluded that successfully tried green building international models such as: LEED®, BREAM®, CASBEE®, ESTIDAMA® or Green Star® can be very useful to manage, plan, design and construct sustainable buildings around the world.
Keywords: Environmental rating systems; Green building; Environmental design requirements; Low carbon architecture.

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1. INTRODUCTION

At present, Mexico does not have a rating system on green building which has been tried or with the potential to solve environmental problems derived from the design, construction, use, maintenance, operability and end of service life of buildings and urban infrastructure, both in the professional and academic sphere.

New scientific knowledge and tools for the transmission of knowledge must be produced in Mexico to actually be able to (academically) educate and (professionally) train urbanists and architects to develop sustainable cities and urban settlements that respond to the current and developmental needs of any country around the world (Hernández-Moreno, 2009: 138).

Governmental authorities must be directly in charge of establishing more efficacious mechanisms and programs, for instance in renewable energies at urban level (Zamfir, 2014), improvement of environmental regulations by sector (forest, food, real estate, industrial, etc.), in public and private spheres that regulate the environmental impacts that promote local and regional sustainable development with a global impact (Hernández-Moreno and Núñez-Vera, 2014) aided by methods and models more efficacious for such objectives.

Recently, in 2013, the Mexican norm NMX-AA-164-SCFI-2013, regarding green building, was issued. It contains baseline criteria and minimal environmental requirements. This norm is an important endeavor to regulate planning, design and construction of buildings, but which on its own, it is not sufficient to align the full cycles of the buildings toward integral sustainability. In like manner, various efforts such as regulated studies on environmental impact requested by SEMARNAT (Secretariat of Environment and Natural Resources), studies on regional impacts requested by some state and municipal agencies of Urban Development, as well as the Code of Green Building (Código de Edificación Verde, CEV-CONAVI) and others are not enough if they are not accompanied by a method or model that integrates all these criteria of sustainable design in construction, so that every effort concurs on the same objectives and goals of reducing environmental impacts in construction demanded by environmental norms such as ISO 15392:2008, regarding Sustainability in Building Construction, or ISO 14000, regarding Environmental Management of goods and services.

The objective of the present document is to put forward a series of design requirements on green building adapted to the Mexican context (table 2) from the review and analysis of a number of proved international models on green building and only for an architectural scale, such as LEED® (U.S.), BREEAM® (United Kingdom), ESTIDAMA® (Arabia), Green Star® (Australia) and CASBEE® (Japan).

These five models and/or environmental rating systems have the common characteristic of comprising several entries or very concise categories on the design and planning of buildings, which decrease local and global environmental impacts caused by them.

LEED® model, owing to various reasons but mainly because it is the most influential in the U.S., is ahead of other similar methodologies and models, and therefore it is the most commonly used (Smith et Al., 2006; Wu et Al., 2016; Da Silva and Ruwanpura, 2009; Pulselli et Al., 2007). LEED® is also commonly accepted in various parts of the world as a reference for design, construction, maintenance and operation of high-performance environmentally-friendly buildings (Da Silva and Ruwanpura, 2009).

Following LEED®, one finds model BREEAM® which has its inception in the United Kingdom, but is widely used in all Europe and even other continents, moreover it was the first green building model (Building Research Establishment, 2016), so its use at international level is also significant and influential.

For its part, the Arab model ESTIDAMA® only has local influence, this mainly due to the factors that are analyzed in this method, which are determined by the particular conditions of the weather and management of resources in this part of the world.

Then the Australian model Green Star® also has its application particularities, however it is known that is similar to LEED® and BREEAM® but its application has only local impact in Australia (Zuo and Zhao, 2014).

Japanese model CASBEE® as ESTIDAMA® and Green Star® are models with regional and local influence.

These models were mainly conceived to certify buildings; however, in the Mexican context, where there is no adequate incentives to motivate the environmental certification of buildings, architects, real estate developers and builders can use these international models (successfully tried already) as references to design and plan, partially or totally, both at professional level and at schools of architecture and urbanism.

From an urban-architectural standpoint, it is necessary to implement and apply several methods, tools and models of environmental design in projects of architecture and cities that allow reducing the noxious effects of carbon global emissions to the atmosphere with the aid and development of various sectors such as energy, water, transport, materials and their residues, etc. (Hernández-Moreno et Al., 2016: 51).

In Mexico, there are no models similar to LEED® o BREEAM®, but there is a Code of Housing Construction by the National Housing Commission (Comisión Nacional de Vivienda, CONAVI), which in its part VI, chapter 27 referring to sustainability, breaks down a series of recommendations and strategies of environmental design for urban and architectural projects (Comisión Nacional de Vivienda, 2015) and comprises the following categories: energy, renewable energies, water, green areas, climatic maps. The

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part regarding construction materials is included in the 5th part of CEV-CONAVI, it deals properly with the construction of the building (Comisión Nacional de Vivienda, 2015: 255-298).

2. METHODOLOGY

The first part of the methodology to analyze these five international green building models basically consists in the review of the scientific literature of such green building models and methods, which have been successful in a certain context. Firstly, it is necessary to select such international models already tried and measure their impact and efficaciousness on the region in real terms. The first selection criterion was to choose at least one per continent, save Africa, as no prevailing model for the region was found, however we reviewed the model called The Green Pyramid Rating System®, which is only applied in Egypt and is based on the American LEED®, which is already considered in the present study.

Once the models were selected, they were analyzed by their regional and international impact, and finally, we analyzed each of the variables associated to the categories of design and environmental planning of the models according to the sort of variable, which may be: natural, human, technologic or economic (table 1), and find out which categories of environmental design from the selected models are applied in an integrated manner. This way, the categories or entries of sustainable design propitious to the economic, environmental and cultural conditions of Mexico were proposed, discarding the design requirements that cannot be applied to the Mexican context.

These strategies and requirements of design and environmental planning of buildings, proposed for the Mexican case, were integrated as a checklist (table 2) proposed both for new and existing buildings and only as a reference to environmentally design and plan buildings, not to be a certification rating system, however in the future this may be the base for a model to certify environmental buildings in Mexico, but for the moment it is not part of the objectives of the present study.

3. RESULTS

3.1. International models on design and construction at a spatial-architectural scale

Table 1 summarizes the analysis of the variables associated to the categories of environmental design and planning each model has according to the sort of variables that can be: natural, human, technologic or economic; which will be useful for the proposal of the checklist for the Mexican context.

TABLE 1 - VARIABLES OF SUSTAINABLE DESIGN ASSOCIATED TO THE ENVIRONMENTAL CATEGORIES OF THE SELECTED GREEN BUILDING MODELS

Categories		Selected green building models					
Sort of variable	Variable	LEED® USA	CASBEE®	BREEAM®	ESTIDAMA®	Green Star®	GBC® ITALY
Natural (environmental)	Sustainability of the place	Yes	Yes	Yes	Yes	Yes	Yes
	Regional priority	Yes	Outdoor environment	In BREEAM® *Communities®*	NO	NO	Yes
Human (Social)	Indoor environmental quality	Yes	Yes	Yes	Yes	Yes	Yes
	Outdoor environmental quality	In site	Yes	In pollution	Yes	Yes	In site
	Historic value of the building	In LEED® *Neighborhood Dev.®*	NO	NO	NO	NO	Yes
Technological	Location and transport	Yes	Surroundings of the place	Yes	Yes	Yes	Yes
	Material and resources	Yes	Yes	Yes	Yes	Yes	Yes
	Innovation	Yes	NO	Yes	Yes	Yes	Yes
Economical	Energy efficiency	Yes	Yes	Yes	Yes	Yes	Yes
	Water efficiency	Yes	In resources	Yes	Yes	Yes	Yes
	On the quality of the building	In LEED Canada®	Yes	In management	NO	NO	NO
	Management	Yes	NO	Yes	Yes	Yes	NO

Note 1: negative answer refers in all cases that the model does NOT explicitly includes deteminate variable but may include it briefly or implicitly in some category.

(Source: authors' own elaboration based on the studied models).

3.2. Brief description of the reviewed models

LEED® version 4 comprises 8 categories and each has a series of environmental design requirements, which being considered in the project will noticeably decrease environmental impacts caused over its entire life cycle (United States Green Building Council, 2014; United States Green Building Council, 2017).

LEED® is considered the most resorted method in the world for environmental certification and design in buildings, owing its prestige and availability (Nguyen and Altan, 2011). The most important categories in LEED®, and which are very useful in the proposal put forward later in the text, are: sustainable design of location and transport; sustainability of the place; energy and atmosphere, water efficiency; materials and resources; indoor environmental quality; innovation; and, regional priority.

With more than 5000 projects certified with LEED® only from 1998 to 2005, this model is considered one of the most successful in the world (Wu et Al., 2016).

Since the goal of sustainable design is to improve the processes to obtain a good product, in this case a building that meets minimal environmental requirements. LEED® has been adopted and adapted in a very flexible manner in various countries (Mousa and Farag, 2017: 574) not only in the United States, but it also has extended to other continents, mainly adopted by developed countries (Mousa Farag, 2017: 572-574). In the case of the Mexican context, LEED® is the most used model primarily owing to its proximity with the United States and the existence of Mexican certifiers that can perform the assessment.

Japanese model CASBEE® (Comprehensive Assessment System for Built Environment Efficiency), as stated by the name, measures and assesses the efficiency and quality of the build environment under sustainability criteria using two sorts of environmental assessment: the first regarding the building's

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environmental quality, and the second, the reduction of supplies for the building. The building's environmental quality, for its part, is assessed by means of the following concepts (Japan Sustainable Building Consortium, 2014), which on their own have to comply with a number of environmental design requirements that can be reviewed in the aforementioned document: indoor environment; quality of the building's service and outdoor environment and analysis of the place; the reduction of building's costs, is analyzed by means of the following concepts (which have to comply with various requirements of environmental design): energy, resources and materials and surroundings of the place.

Although CASBEE® is a very well structured model, it slightly differs with the ways of thinking and making architecture and buildings in Mexico, so it would not be economical to adapt an Asian model and bring certifiers simply to certify a building.

BREEAM® (Building Research Establishment's Environmental Assessment Method) is the first model, method and/or schema for green building rating system in the world; it came from the emerging needs regarding the heavy environmental impacts from design, construction, use, maintenance and operability of buildings (Building Research Establishment, 2016). Since it is the first model of its kind, it has influenced LEED®, and on for its part, it has become the most influential in the world, due to the impact of the U.S. in construction and real state development; this way, it can be said that directly or indirectly BREEAM® is the model with the greatest impact in the world.

BREEAM® is composed of the following categories of environmental design that have to comply with various requirements of environmental design: management; health and wellbeing; energy; transport; water; materials; waste; land use and ecology; pollution and innovation. The case of BREEAM® is similar to that of LEED® regarding thinking and doing architecture, the problem is the distance from Mexico to the United Kingdom to opt for this model certification.

In 2010, Abu Dhabi Urban Planning Council launched an initiative with a vision for 2030 called Estidama (Abu Dhabi Urban Planning Council, 2010). Such initiative includes a scoring system to assess the building's sustainability conditions in a similar way to LEED® or BREEAM® that is called Pearl Rating System, which nowadays is only compulsory for the Emirate of Abu Dhabi, in the rest of the Emirates it is voluntarily applied.

Distinguishable is the especial attention paid to water care (in fact, the chapter devoted to the topic is called Precious Water). If we look for a climatic equivalent for Abu Dhabi in Mexico, we will find it with differences, in Mexicali and surrounding areas. These cities exhibit temperatures and yearly rainfall so similar that there are fewer differences than those between Mexicali and Hermosillo; as a matter of fact, the capital city of Sonora receives three times as much rain as Mexicali.

There is only one sensible difference between the temperatures of Abu Dhabi and Mexicali: here in winter central heating is needed, as it is farther from the equator, winter nights are longer and daylight reduces.

Pearl Rating System consists of the following categories: integral development processes; natural systems, inhabitable buildings, precious water; renewable energies, material management, innovative practice.

To sum up, it can be said that Pearl Rating System shows a series of assessment elements that might help to a varying degree in the Mexican territory. Putting aside the utterly different budgetary capacity of Abu Dhabi, the system will find many applicability points in Mexicali and surrounding areas; to a lesser extent, it might also be useful in other desert regions in northern Mexico; however, at any point of the national territory some precepts that have to do more with ethics in design than with accurate technical regulations will be valid.

Australian model Green Star® is a voluntary certification that assigns six values or stars according to the quality of building practices (it is considered there is a seventh value equal to zero: “0”, which refers there is no other quality control in the building). It is composed of environmental design categories in addition to have goals in leadership, innovation, environmental administration and social responsibility (Green Building Council of Australia, 2017).

The categories of Green Star® are the following: 1. Management: it is the administrative assessment of the building by professionals accredited by Green Star®; 2. Quality of the environment inside the building; 3. Energy; 4. Transport; 5. Potable water; 6. Materials; 7. Use of land and ecology; 8. Emissions; 9. Innovations in the building.

Therefore, we the authors consider that it is a model that in spite of being Australian and the distance between Mexico and Oceania is noticeable, it is an occidentalized model and very similar in requirements and criteria to BREEAM® or LEED® and can be taken as a partial reference for projects in Mexico, not to certify properly, but as a reference to approach the variables of design and green building.

The assessment system GBC HISTORIC BUILDING® ITALIA (Green Building Council Italia, 2016) for Historical Buildings based on LEED®, however adapted to the Italian context, unlike other systems of sustainable certification of recent buildings such as LEED®, CASBEE®, Estidama®, Green Star® and other systems known nowadays, focuses on the historical value of buildings and their modifications and interventions as well as on the criteria to consider within sustainable objectivity, the criteria are the following: 1. Historic value; 2. Sustainability of the place; 3. Water management; 4. Energy and environment; 5. Materials and resources; 6. Indoor environmental quality; 7. Innovation in design; 8. Regional priority.

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3.3. Proposal of basic requirements by category of environmental design for sustainable design and green buildings in Mexico (Checklist)

Based on the results of the analysis of the design variables associated to the environmental categories of the studied models (table 1), a proposal, in a checklist format, was put forward (table 2) in order to establish the basic requirements by environmental design category that any model or Mexican method on green building has to meet.

TABLE 2 - SUSTAINABLE ARCHITECTURAL DESIGN REQUIREMENTS BY CATEGORY AT ARCHITECTURAL SCALE FOR THE MEXICAN CONTEXT

Categories:		Sustainable architectural design requirements (architectural scale)
Sort of variable	**Sustainable design variable**	
Natural (environmental)	Sustainability of the place and outdoor environmental quality	1. Assessment of biotic and abiotic resources of the place and analysis of the equipment and urban infrastructure and land use
		2. Protection and restoration of the habitat including the avoidance of protected areas
		3. Wind control
		4. Rainwater and flood control
		5. Reduction and mitigation of heat islands
		6. Reduction of light and noise pollution and from bad odors
		7. Prevention of pollution from construction and maintenance
		8. Right orientation and placement of the building
		9. Management plan of external works
		10. Landscape protection and erosion control
	Regional priority (urban scale)	1. Community management and participation to develop or modify urban development plans
		2. Priorities and needs of the population
		3. Infrastructure services, urban equipment and services ecological in nature
		4. Consider the local uses and customs in design and planning
		5. Inclusive design (disabled people and with special needs)
		6. Offer suitable air quality in the cities (quantifiable)
		7. Regional and global energy reduction by using clean renewable alternative energies with low carbon footprint in the cities
		8. Advantages and opportunities for economic development for the zone (advantages and opportunities for business, government and citizens)
		9. Prevision and provision of use of land
		10. Plan of urban mobility and interconnectivity, preferably for pedestrians, with ecologic transport and low energy consumption
		11. Sustainable management of parks and garden in the cities (reforestation and greater carbon sequestration).
		12. Integral management of city waste, including construction waste
		13. Planning of durability and service life of components and buildings. Information useful for the calculation of carbon footprint of the construction materials

Categories: Sort of variable	Categories: Sustainable design variable	Sustainable architectural design requirements (architectural scale)
		14. Preservation of land, air and water in the cities
		15. Prevention and mitigation of risks in the cities
		16. Avoid places vulnerable to risks (e.g., flooding or protected such as natural reserves. Review and consult the Plan and Programs of Urban Development of the place)
		17. Analysis of urban equipment and infrastructure (to find out the impact range of the project), (for instance for a possible arrival in bicycle or motorbike, or prevent bad odors, noise, or light pollution). Of course, to improve public services in the zone.
		18. Erosion control and management plan for the landscape around the place. (Proposal to prevent erosion during and after construction), (gardening proposal using endemic vegetation, adequate for winter and summer, depending on the building orientation, weather and sort of construction).
		19. Transport alternatives in the place: (consider parking areas for bicycles and motorbikes, as well as accesses and routes). Includes the strategic assessment of transport, safe, comfortable and attractive streets, bike lanes and improvement to ecologic low-energy public transport.
Human (Social)	Indoor environmental quality	1. Air quality optimization, including moisture control
		2. Avoid tobacco smoke
		3. Use of materials and finishes of low toxic emissivity
		4. Management plan for the quality of air during construction, use and maintenance of the building
		5. Air quality verification
		6. Thermal comfort (both active and passive)
		7. Lightning comfort (both active and passive)
		8. Acoustic comfort
		9. Bad odor control
		10. Optimal visual relief
		11. Prevention of vibrations in structures and latticework
		12. Control by occupation and ergonomics
	Historic value of the building	1. Intervention of the specialist in architectural heritage and landscape
		2. Preliminary research of the historic building
		3. Research on advanced knowledge about energy in the building
		4. Research on advanced knowledge about diagnosis tests in materials and forms of degradation
		5. Research on advanced knowledge about diagnosis studies and structural monitoring
		6. Reversible intervention in preservation
		7. Compatibility of expected use and its benefits
		8. Structural compatibility regarding the existing structure
		9. chemical and physical compatibility of mortars and other restoration materials
Technologic	Location, transport and mobility	1. Location for the development prioritizing neighborhoods
		2. Priority of use of land according to low-carbon planning

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Categories: Sort of variable	Categories: Sustainable design variable	Sustainable architectural design requirements (architectural scale)
		3. Diversify and densify the uses of land (compaction)
		4. Accessibility to transport routes
		5. De-motorization of transport (bicycles)
		6. Reduction of parking for private vehicles
		7. Use of eco-fuel vehicles
		8. Preference for the use of public transport systems
		9. Improvement of transport infrastructure (transport and intelligent and sustainable mobility)
	Materials, waste and resources	1. Recollection and storage of recyclable products
		2. Reuse of waste from constructions and demolitions
		3. Reduction of impacts from the materials' life cycle analysis
		4. Use of environmentally certified and endorsed materials (low environmental impact and low carbon emissions)
		5. Avoid the use of materials that surpass toxic contents
		6. Design and build to deconstruct, not to demolish
		7. Use of recyclable and reusable, biodegradable and natural materials
		8. Use of materials preferably ceramics over metallic and polymers
		9. Reduction of building volumes and architectural spaces
		10. Use of locally-produced materials
		11. Use of durable materials
		12. Reduction of waste and refuse over the entire life cycle
		13. Suitable management of hazardous waste
		14. Reuse of buildings, components and installations
		15. Flexible design
		16. Recycle and reuse of wastes
		17. Separation and rating of wastes and rejects over the entire life cycle of the building included its correct final disposition
	Innovation	1. Use of nanomaterials to optimize some components and construction systems
		2. Automation of some systems and installations
		3. Use of new construction materials and systems
		4. Implementation and use of parametric design
		5. Implementation and use of digital construction in the building or its parts
		6. Life cycle design
		7. Durability and service life design
		8. Use of new low-carbon models and methods in integral urban-architectural projects
Economic	Energy efficiency	1. Reduce the use of energy both indoors and outdoors
		2. Optimize energy performance, actively or passively
		3. Use of advanced technology to measure and monitor energy
		4. Cover the totality of demand in the building
		5. Use and production of renewable and alternative energies

Categories:		Sustainable architectural design requirements (architectural scale)
Sort of variable	**Sustainable design variable**	
		6. Improvement in the use of refrigerants and related supplies
		7. Use of green energy and apply carbon offsets
		8. Building orientation for gain and loss of heat
		9. Optimization of the envelope and sealing of the building
		10. Provide natural lightning
		11. Provide natural ventilation
		12. Passively ventilate, heat and cool
		13. Natural control of moisture in the building
		14. Application of saving systems and equipment to clean, illuminate, ventilate, cool or heat
		15. Automation of some active illumination systems, air conditioning, heating, security, firefighting systems, etc.
		16. Optimize the performance of the systems both passive and active
		17. Use of saving equipment and apparatuses
		18. Installation of reducers and capacitors in electric installations
	Water efficiency	1. Reduction of potable water use indoors and outdoors
		2. Control in water consumption measurement
		3. Use of water in passive climate conditioning
		4. Use of saving technologies in the installations
		5. Reuse of gray water
		6. Waste water treatment
		7. Catchment and use of storm water
		8. Efficiency and minimal use of installations
	Quality of the building service	1. Estimation of service life
		2. Durability plan for the building
		3. Operation and use manual of the building
		4. Maintenance manual of the building
	Management	1. Intervention of a specialist certified in design and construction
		2. Adapt new projects to plans on resilience to the local climate change
		3. Establish the objectives of the building functionality over its entire service life
		4. Define specialized working groups during the design
		5. Foresee measuring and monitoring over service life including assessment of costs by life cycle and analysis of environmental impacts by life cycle
		6. Environmental management over the construction phase including waste and residue management

Source: authors' own elaboration based on the models studied

4. CONCLUSIONS

The objective of the present work was met in such manner that by means of an exploratory and reliable exercise a checklist was integrated and generated with the basic requirements for green building design by category, explicitly well defined, which might be greatly useful as a basis to produce a Mexican rating model on green building.

It is concluded that successful green building international models such as LEED®, BREAM®, CASBEE®, ESTIDAMA® o Green Star® in spite of being from various countries agree in many aspects or variables, being these virtually the same concepts with different definitions and approaches, which additionally can be useful as a reliable reference to manage, plan, design and construct buildings around the world, including countries as Mexico, with suitable adaptions to the environment and ways of designing and building.

There are more green building models, rating systems and methodologies around the world such as German model DGNB®, the French HQE®, the Italian CASACLIMA®, the Canadian GREEN GLOBES®, or Qatari QSAS®, which in spite of being important in their regions, have neither reached the impact nor influence of the models studied in the present work such as LEED® or BREEAM®, which have a high-profile and which have been taken as reliable references around the world, not only for building certification but as a necessary reference in the way of making green architecture both for professionals of the area and architecture and engineering students who increasingly incorporate them in the design process of projects.

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