

Article

Architectural Design: Sustainability in the Decision-Making Process

Margarida Feria ¹ and Miguel Amado ^{2,*}

¹ GEOTPU.LAB – Laboratory of Architecture, Territory and Urban Planning Studies of IST, 1049-001 Lisboa, Portugal; margaridadcferia@gmail.com

² CERIS, Civil Engineering Research and Innovation for Sustainability of Universidade de Lisboa, Av Rovisco Pais 1, 1049-001 Lisboa, Portugal

* Correspondence: miguelpamado@tecnico.ulisboa.pt

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Abstract: This article discusses the potential of introducing sustainability in the architectural design method so that building solutions can contribute to sustainable development. Sustainability has introduced a new pattern to the architecture practice, which involves important modifications in the teaching of architecture in what regards to the design methods to students but also practitioners, in order to provide more comfort for present and future generations. In the design phases of the architectural design, the subject of the three pillars of sustainability—economic, social and environmental factors—are not always considered by the architect in the decision-making process. The topic involves actions that will influence the overall performance of the building throughout its lifecycle. Sustainability has not been a priority in the training of the architect. The existing tools, Sustainability Assessment and Certification Systems, although adequate to evaluate the sustainability component of a building, do not prove to be the most appropriate tool to support architects during the design process. Therefore, the implementation and evaluation of strategies that integrate the sustainability principles need to be included in the early stages of the architectural design method. In addition to collecting data through literature review, a survey was conducted among 217 architects and architecture students in order to assess the need for a tool that supports architects in the issue of sustainability. The results concluded that, although all the respondents agree about what concerns the implementation of sustainability principles in the architectural design method, only few respondents guarantee that these principles are implemented by means of a rigorous evaluation. Thus, the purpose of this paper is to identify a set of guidelines that can help architects to change the current approach of architectural practice towards more sustainable strategies in building design. This means the introduction, implementation and evaluation of sustainability principles in different phases of the architectural design method. The proposal stresses the main strategies that need to be considered in each phase of the architectural project and defines a level of recommendation in each guideline that allows the architect to evaluate the implementation of sustainability.

Keywords: sustainability; guidelines; architectural design method; Assessment and Certification Systems; survey

1. Introduction

The current state of global development poses new challenges to the architectural profession: it must transform and adapt itself in order to ensure a role with greater relevance in the search for effective sustainable solutions.

In this sense, it is important to understand the connection of the architect with the sustainable development, because his relationship with the design practice of the architect sustainability is introduced in the paradigm of architecture as a necessity that entails important modifications in the teaching of architecture as well as the design methods of students and practitioners in order to provide prosperity for present and future generations.

Over the last decades, it has been substantiated that the excessive consumption of natural resources surpasses their replacement time. This scenario is not viable to maintain a balance between the needs of human activities and their adaptation to the environment to guarantee future conditions of enjoyment for the upcoming generations. Since the construction industry is responsible for the exploitation of 50% of the world's natural resources [1,2] it is also one of the sectors that could most contribute to the reduction of environmental impacts.

According to UNESCO and International Union of Architects (UIA), Charter for Architectural Education, "...architecture involves everything that influences the way in which the built environment is planned, designed, made, used, furnished, landscaped and maintained" and so "...architectural education constitutes some of the most significant environmental and professional challenges of the contemporary world"[3].

It is expected that the construction sector will continue to grow in the next years as housing demand increases globally [4]. According to The Global Status Report 2017, over the next 40 years, the sector floor area of buildings will double, adding more than 230 billion square meters in new construction [5]. Therefore, it is important, as a global measure, to know how societies' development models can maximize sustainability in order to foster social, economic and technological progress with the efficient use of natural resources and energy. To achieve this goal, it is necessary to change the current approach of architectural practice towards more sustainable strategies in building design. This means that the practice of architects should be re-designed to accommodate a better understanding of the effects of climate change in a rapidly urbanization process and an economic crisis [6].

2. Literature Review

The principle of sustainable development emerged as a response to the general panorama at the end of the 20th century, which was characterized by rapid industrial development and the considerable increase of the world population [7] that led to an uncontrolled exploitation of natural resources.

Since the 1970s, a set of international political agendas have been proposed, calling for cooperation between nations and the various sectors of human activities. The Brundtland Report has become one of the most important reflections on sustainable development since it allied the need for economic growth to environmental and social issues. Also called "Our Common Future", the Brundtland Report was released in 1987 by the World Commission on Environment and Development of United Nations and defined for the first time the concept of sustainable development as "(...) development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[8]. The interpretation of Brundtland's definition suggests that to acknowledge the sustainable component of a building, it is important to consider the environmental, social and economic dimensions of sustainability.

In 1994, the concept of sustainable construction first appeared during the First International Conference on Sustainable Construction in Tampa, Florida, where different approaches were communicated towards a definition of sustainable construction. At the conference, Charles Kibert presented the concept of greater consensus for the sustainable construction sector, defining it as "the creation and operation of a healthy built environment based on ecological principles and resource efficiency" [9], considering soil, materials, energy and water as the most important resources for construction. It is from these resources that architects need to establish the use of the following principles to a sustainable construction [10]:

- Minimization of resource consumption;
- Reduction of maintenance necessities;

- Recycling of materials at the end of the building life cycle;
- Protection of natural systems and their function in all activities;
- Promotion of the quality of the built environment.

Throughout the building life cycle, sustainable construction presents multiple advantages. It has a positive impact on the environment through energy conservation, saving water and other resources, use of reusable, natural and local materials, reducing pollutant emissions, recycling life cycle waste of the constructions and increasing building durability [11,12]. It also has positive social effects: guaranteeing users' health and comfort through indoor air quality and acoustics comfort, as well as accessibility, security and preservation of cultural heritage. Moreover, sustainable construction also provides economic benefits in the long-term.

The role of sustainable construction is also reinforced by Sustainability Assessment and Certification Systems that allow estimations of the level of efficiency and sustainability achieved by improving the quality and performance of buildings. These systems evaluate environmental, economic and social dimensions of sustainability and are greatly increasing the attention towards sustainable assessment of buildings [13–15].

Even though sustainability assessment tools are valuable to verify if a building is sustainable, they are mostly developed to evaluate the construction only after it is built and are not suitable to assist architects in building design because they do not approach specific strategies to guide practitioners [16–19]. Also, the possibility to reduce negative impacts of a building is greater in the design phase, when approximately 80% of the building consumption is defined [10].

Since the decisions made during the design phase will influence the building's performance throughout the rest of its lifecycle, it is important that architects consider sustainability principles during the design process. This is possible through the linked and weighted implementation of preventive and passive strategies over active strategies [20]. Also, architectural professionals have an important role to future low energy in sustainable buildings, since it is in the design phase where the decisions take place [21].

The implementation of such strategies can be aided by a tool that can support architects in the implementation of sustainability principles during the architectural design process [22].

2.1. Architectural Design Methods

The design studio is the most effective architectural education and methodological training tool. The studio functions as a pedagogic constructor in which acquired knowledge and skills are applied in the design process through problem solving.

It is predicted that in the design studio the application of previous theoretical knowledge and the acculturation, which influences the definition of the concept, will allow the architect to find the solution to the problem.

Rapid development in the knowledge generated and the empowerment promoted, skills, methods and tools for the design domain have a direct impact on the way the activities are conducted in the studio [23]. It is important to consider the learning process of design in the studio as one that in its practice assumes a form of collaborative work and knowledge integration.

Architectural education must inspire creativity and innovation, but also dialogue, inclusivity and critical thinking to reinforce determination towards operative communication and team collaboration [24].

It is very important that the education in architecture is sufficiently strong, so that the students acquire skills and competencies to deal with the sustainability issues in the future [18–25].

There are different perspectives on the architect's role in the process of creating and transforming spaces. On the other hand, the origin of ideas, decisions, values and selected references are attitudes depending on a personal understanding of the reality of all the principles of sustainability [26].

In this paper we do not consider the activity of the architect who does not design but still has an administrative role in public activities.

Sustainable principles need to be consciously integrated into the architectural design method to establish a solid and coherent foundation for sustainability throughout the remaining life cycle of the building [10]. Architectural design methods must be studied in order to understand how they can adapt to the requirements of the present and the needs of the future.

In the field of architecture, there is a lack of a body of theory to support the study of architectural design methods [27,28]. Thus, it is essential to review and reinterpret concepts from other fields of study.

[29–32] identify the following normative models, currently used in urban planning, as some of the most important: Synoptic or Rational Comprehensive, Incremental, Transactive and Advocatory. However, within the field of existing planning models, it is still fundamental to mention the Scientific Method that is widely used by architects.

Table 1, adapted from the work of [30] to fit the scope of architecture, compares the theoretical planning models regarding their relation to the promotion of sustainable development in architecture. It can be concluded that, although the models may contribute to the implementation of some strategies that promote sustainability, none of them reflect a direct tendency towards the aims of sustainable development. This in turn suggests that there is the need to analyze a new planning model, integrable in the architectural design method, which adheres to the framework of all the principles of sustainable development.

Table 1. Schematic overview of various planning theories.

Header	Global/National Environmental and Resource Concerns	Local Environmental Concerns	Fair Distribution of Benefits	Respect for Human, Political and Civil Rights	Potential for Change of Societal Frame Conditions
Synoptic	(+)	(−)	(+)	(−)	X
Incremental	-	-	-	(+)	(+)
Transactive	(−)	(+)	(+)	+	+
Advocatory	X	+	(−)	+	+
Scientific	(+)	(+)	(−)	X	(+)

+ usually well suited, (+) may be suited under certain condition, X no evidence, (−) may cause negative effects; - usually has negative effects. Source: [30] (adapted).

Architectural design methods require a simpler, flexible and inclusive planning model that provides a connection with the objectives of sustainable development and therefore anticipates the long-term effects of constructions in the environment.

Considering that the architectural design method complements at least four phases: program definition, feasibility study, preliminary design and detail design, each of these phases is implemented by a decision-making process which involves: analysis, synthesis, evaluation and decision [31,33–35]).

[36] consider the method as being a multidimensional construction of a more processual nature and identify indicators of academic engagement from a multilateral perspective as three stand points: behavioral, cognitive and affective.

Regarding architectural design methods, they contemplate sustainability issues, the phases of analysis and whether synthesis should be responsible for the implementation of sustainable principles, while the evaluation phase should validate the conformity of the hypotheses with the established principles (Figure 1). As concluded by the developed survey, the evaluation phase is often empirical or non-existent among architects, which exposes the lack of a systemic assessment method with a theoretical basis that can guide architects during the assessment phase [37].

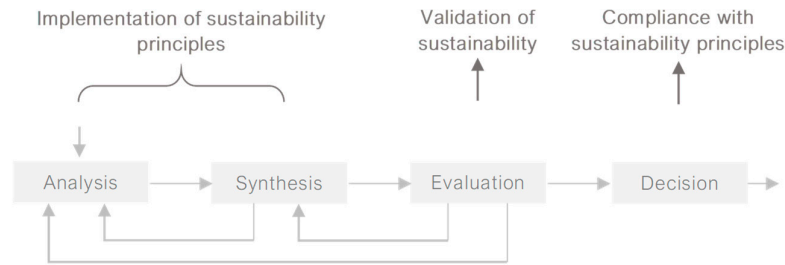


Figure 1. Decision-making process to implement sustainability. Source: [34] (adapted).

2.2. Key Indicators of Sustainability in Architectural Design

In order to measure the sustainability of the implemented solutions, key indicators must be identified. These indicators ensure that all principles and components of sustainability are systematically considered in the architectural design method. Although Sustainability Assessment and Certification Systems “are not originally designed to serve as design guidelines” (Ding, 2008:456), it is possible to rely on these tools to identify key indicators that can measure the sustainability of various solutions during the design process.

Sustainability Assessment and Certification Systems are technical instruments that identify, predict and evaluate the environmental impact of buildings and then assign a level of certification related to the accomplishment of sustainability principles [14,38]. The evaluation of most of these systems is based on the attribution of credits or points when certain parameters are met. These parameters are organized by categories and vary according to the assessment system. Each category is given a specific weight according to its importance in relation to the level of sustainability in construction. The sum of the various scores attributed to each category results in a graded classification for the sustainable performance of the building.

According to different studies [38,39] that compare different assessment and certification systems, the categories that present the highest weights are the environmental loading, internal environment, external environmental impact and resources. In general, the areas most linked to the environmental component are more relevant compared to socioeconomic and political factors, planning and innovation.

The weightings of the systems are determined according to the degree of importance assigned to each of the categories of evaluation, and these are directly related to the situations of each country. Among the several systems, the energy efficiency requirement is consistently assigned a higher value as it is recognized as one of the most urgent needs. Great importance is also given to the nature of the materials, conservation of potable water and to parameters related to indoor environmental comfort such as visual, thermal and acoustic comfort as well as indoor air quality.

Based on these weightings and considering the architects’ thinking-process in architectural design, the following five key sustainability indicators were selected: energy efficiency, potable water conservation, indoor air quality, acoustic comfort and project durability. These were considered the most representative and suitable to be integrated in the methodological framework of architectural design methods [40].

By implementing strategies that contemplated the selected five key indicators, in all the phases of the architectural design method, other sustainability parameters could be determined, but also the sustainability of the project could be guaranteed.

3. Research Methodology

This research combines theoretical and empirical evidence, that is, establishment of a theoretical framework in order to ensure the adequacy on an empirical and holistic approach. The methodology has been defined to allow the understanding of the relationship of the design practice of the architect with the sustainability. In this way, the research adopts a sequence of four steps that enabled to

quantify the principal factors considered by architects and architecture students in introducing sustainability issue in the architectural design.

In its first step, the research was done at the level of the presuppositions for the understanding of the architect's knowledge of Sustainable Development and its relationship with the architect's design practice. The fact that architecture involves a huge number of relations between the natural and built environment as well as the social requirements of human activities, through which the main factors need to be identified for their efficient performance in design. To reach an understanding of the current state of the real necessities of architects and the advantages of existing system to help to implement the principles of sustainability in design, the research considered the definition of a list of indicators that can be representative of sustainable development applied to architecture design [10]. The second step of the research process has been a development of a survey to professional architects and architecture students from different countries and with different backgrounds, with the objective to create a framework of the skills they must have to deal with the subject of sustainability applied to design [41]. The third step was assessing the group of indicators related to sustainable principles that must be considered in all design processes conducted by the architects who participate in the fourth step of the research process with the proposal of guidelines to assist their practice.

This research resulted in the identification and formulation of a structure of design phases and a list of guidelines supported in a strategic thinking of architect to implement sustainability in design (Figure 2).

STEP 1	Literature review
STEP 2	Survey
STEP 3	Selection of indicators
STEP 4	Proposal of guidelines

Figure 2. Research method.

4. Survey

The actors involved in the design of architectural projects and the trainers of future architects need to collaborate and develop new and different teaching approaches that promote skills and competences for future professional practice. The requirement that sustainability introduces in the design process demands from the architect the ability to develop strategies and new guidelines for the project.

The opportunity for the architect to work with a multidisciplinary team requires new ways and means of communication. Engineers and architects possess such skills, however, most architects do not know how to restore to empirical tools or bypass the deeper approach without a visible result.

The opportunity to extend the set of principles introduced in the design process reduces the communication issues between architects and engineers, leading to new ways in which the more humanistic, philosophical and cultural approach to architecture is able to proceed towards the positivist attitude of the engineer where subjectivity is non-existent.

An online survey was conducted to assess architectural professionals and architecture students to analyze and understand their viewpoints and opinions about the necessities on the advantages of creating a system that can support architects in the implementation of sustainability principles in the design process [41].

The developed survey yielded 217 responses and the statistical results are presented in Appendix A—Table A1. The survey and the number of questions are sufficient and sensibly effective to obtain data related to what issues are of importance and what architects do to deal with sustainability as well as what method they apply.

All the respondents (100%) considered that sustainability should be implemented in the architectural design process (Question 2), even though approximately 46% of them said that they evaluated the implementation of sustainability empirically and 30% of the respondents do not evaluate the sustainability component of their projects at all (Question 3). This indicates that a

systematic evaluation, with a theoretical foundation, is not part of most respondents' architectural design methods.

When asked if Sustainability Assessment and Certification Systems were adequate to support architects during the design phase (Question 4), only 26% of the respondents considered these factors appropriate, whereas most of the respondents (72%) did not know. When questioned about which of the methods was most effective to ensure the implementation of sustainability (Question 5), almost half (49.3%) stated that the Systematic methods with theoretical foundations adapted to architectural design process was the best one and approximately a third (31.8%) of them admitted not knowing. It is crucial to notice that, although 46% of the inquired said that they used an Empirical Method to evaluate the implementation of sustainability, only 3% considered it the most suitable method.

To provide respondents with the opportunity to express additional opinion, one optional open-ended question enabled them to write any comments related to what they consider necessary for developing guidelines for a sustainable project.

Overall, it can be understood that, although all the respondents agree that sustainability principles should be implemented in the architectural design process, only few respondents guarantee that these principles are implemented by means of a rigorous evaluation. This, in turn, highlights the need for a system that supports architects in guaranteeing sustainability as an integral part of architectural design method.

5. Guidelines to Sustainable Architecture Design

Implementing sustainability into architectural design methods requires sustainability principles to be considered from the beginning of the design process [42]. In order to assist architects in selecting the best strategies and verify their alignment with the aims of sustainability, guidelines for a sustainable project have been developed. These guidelines were determined from the previously selected key indicators of sustainability [43].

An integrated approach to sustainability leads to a design solution where the technical aspects are inserted into the design process. In the sketching phase, the project becomes better defined and the indoor environmental conditions and the energy frame of the building are starting to become determined by the design [44]. This decision is also important for the level of comfort, and for a quality working environment for future users. From an economic point of view, the operating costs can be reduced to a minimum when the climate screen of the building considers passive strategies, thus, saving energy for cooling and heating, and the passive ventilation principles employed also reduce energy consumptions.

Therefore, it is important that the design process takes into account the passive strategies in different phases of the operative process:

Analysis—site analysis (history, architecture, genius loci, green structures, infrastructure, equipment and facilities in the area and the social structure of inhabitants). Comfort analysis (based on CR 1752). Climate analysis (solar data and calculations of altitude and azimuth, temperature, rainfall, humidity, prevalent wind). Regulation analysis of legislative demands (building codes and municipality documents).

Sketching—Site plan. Solar simulations of site plan in order to identify shadows from buildings and other volumes. Green roofs to save rain water and influence the level of humidity. Daylight levels in the middle of the buildings and glare risk. Identify the *U*-values to the site and uses requirement (insulation thickness). Simulation of heating and cooling load. Ventilation passive strategies (natural ventilation, dimension and placement of windows). Atriums in relation to entrance area in the dwellings. Open floor plans. Construction system (structure). Physical models or virtual models to help to understand the scale and shape.

Synthesis—Ventilation passive strategies (natural ventilation, dimension and placement of windows). Calculation of the heating and cooling load. Selection of interior materials based on space acoustic performance. Criteria selection of materials based on Life Cycle Assessment (LCA) balance. Calculation of a structural detail (timber, iron or concrete). Calculation of minimal ventilation rate and the opening area of the windows to maximize the result. Physical models or virtual models.

All of these different parameters were integrated in the design process at various stages as tools rather than obstacles. These principles need to be understood as a natural part of the design process.

In this context, the proposed guidelines summarize and evaluate the main strategies and principles that need to be integrated throughout various design methods phases to ensure that sustainability principles are considered in the architectural design process [45]. Each guideline was given a recommendation level, outlined in Appendix B—Table A2, to specify the degree of importance of implementing each strategy. Moreover, additional specifications for certain guidelines have been included for further explanations or suggestions where necessary.

Each strategy has been integrated into one of the four phases of the architectural design method according to its level of detail. However, the presented guidelines admit multiple interactions and feedback loops between various design phases according to the thinking process of each architect.

If possible, the architect should always prioritize the implementation of passive strategies. In addition, the final decisions concerning the implementations of each strategy must be treated responsibly and adapted to the context of the site.

The structure of the proposed guidelines is presented in Table 2 and the guidelines can be found in the Appendix B—Table A2 A, B, C and D.

Table 2. Guidelines Structure.

Guidelines Structure
Table I. Program and Data Collection
Passive Strategies
i. Site and Climate
ii. Urban Context and Conditions
iii. Adapting the program to the site
iv. Internal consumption and needs
v. Other Criteria
Table II. Feasibility Study
Passive Strategies
i. Siting
ii. Orientation
iii. Form
iv. Envelope
v. Landscape
Table III. Preliminary Design
Passive Strategies
i. Structure
ii. Internal layout
iii. Opening elements
iv. Shading elements
v. Natural Ventilation
vi. Additional energy efficient strategies
Active Strategies
vii. Heating and Cooling Solutions
Table IV. Detailed Design
Passive Strategies
i. Materials Selection
ii. Thermal Insulation Materials
iii. Construction Details
iv. Water Fixtures
v. Building Management
Active Strategies
vi. Low Consumption Devices Selection

I. Program and Data Collection

The program is the starting point of any architecture project, when the general requirements of the overall design are defined. To guarantee the sustainability of the project, the architect should consider the bioclimatic characteristics of the site [46–48] as well as the best energy efficiency strategies and the possibility for potable water conservation. Impermeabilized areas should be minimized and adapted to the profile and number of users, functions of the future building and typology of spaces in order to reduce damage in ecosystems and natural resources. It is also important to estimate internal consumption and needs of the future building and to study other significant criteria concerning social, cultural and economic context.

II. Feasibility Study

The feasibility phase is crucial to ensure energy efficiency, since it determines how the building is formally integrated in the surrounding environment. Issues such as orientation and form, determined in this phase, will have a huge impact on the energy performance of the building in the operation phase. Therefore, it is important to prioritize daylighting, natural ventilation and passive design solutions for heating and cooling, using mass, landscaping and design to work with topography and climate [46,47,49].

III. Preliminary Design

In the preliminary design phase, the design team experiments with internal layout, dimensioning of areas and heights, and elements regarding the envelope of the building as opening elements and shading systems. These decisions are key determinants for the energy efficiency of the building.

Active strategies for heating and cooling systems, powered by renewable resources, should also be addressed so that such systems can form an integral part of the building and the use of prefabrication [50].

IV. Detail Design

In the detail design phase, final considerations are decided regarding the layout and dimension of interior spaces. Materials and finishing materials, water fixtures, electrical equipment and artificial lighting are selected. This phase is still very important for the implementation of sustainability since these strategies will have a great impact on acoustic comfort, indoor air quality, energy efficiency and durability of the building. Moreover, water fixtures choice will impact potable water conservation [51].

The previous guideline structure defines a contribution for a more sustainable solution of architecture design, that can be achieved through management of many principles that should be considered and integrated in the project by the creation of more holistic approach [52].

The results show that there will be a positive impact on this relevant theme about guidelines on sustainable design architecture.

6. Conclusions

Sustainability can be understood as a set of ethical values based on social, environmental and economic responsibility. Through these values, it is possible to reach sustainable development, which, should urgently emerge to replace the current development model of societies.

The practice of architecture is a driver to achieve sustainable development, yet most architects do not address this issue in their projects. The study of architectural design methods reveals the need for a new, simpler, multidisciplinary model that implements sustainability within the design process. An evaluation of the sustainability component in the design process who is often nonexistent among architects or it lacks a systematic and theoretically based evaluation methods. This understanding highlights the results of the survey where almost half (49.3%) of the survey respondents stated that the Systematic methods with theoretical foundations adapted to architectural design process was the best one even though approximately a third (31.8%) of them admitted not knowing.

In response to this need, an evaluation system was developed, formalized in guidelines, which were structured according to the phases of the architectural design process. These guidelines inform architects of the main strategies required to achieve sustainability goals as well as to optimize the design process.

The guidelines are also suitable for determining whether a building contributes for sustainable development.

Furthermore, the aim to raise awareness regarding the sustainability in the field of architecture still very rarely implemented. Thus, the proposed system suggests a transition from a theoretical concept to one that can be practiced and conducted to the implementation of a more sustainable architecture design with strategies and tools in practice, and with support from informative guidelines built for architects and other technicians and stakeholders.

The guidelines raise several possibilities for future developments and adaptations by the architects. They can evolve into an interactive model in the form of a checklist, which helps to reduce the error and the risk in the decision phase. In addition, the content of the guidelines could be further developed and expanded to include other sustainability indicators more focused on the social and economic dimensions of sustainability.

Another outcome would be the computerization of the developed tool or its incorporation in a 3D design software for architecture. This would allow the design team to more accurately evaluate the implementation of sustainability principles while developing technical drawings and visualizations. Such evaluations would not only include the assessment of energy performance of a building, as it is already done by several software programs, but also other key indicators of sustainability.

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Appendix A

Table A1. Statistics of respondents.

1. Clarify your professional situation:	
Answer	Ratio
Architecture student.	32.3%
Architect and is responsible for designing projects.	37.3%
Architect and collaborates in the design of projects.	22.1%
Architect but does not practice the profession.	8.3%
2. Do you think that the concept of sustainability should be contemplated during architecture design process?	
Answer	Ratio
Yes.	100%
No.	0%
3. How do you evaluate the implementation of sustainability in your projects during the design process?	
Answer	Ratio
I evaluate empirically.	45.6%
I use an evaluation system developed by me or my team.	13.8%
I use commercial evaluation systems (i.e., LiderA, LEED, BREEAM, CASBEE).	7.8%
I do not evaluate.	30.0%
Other.	2.8%

4. In your opinion, are commercial sustainability assessment and certification systems (i.e., LEED, BREEAM, CASBEE) adequate to support the design phase of the project?	
Answer	Ratio
Yes.	25.8%
No.	2.3%
I do not know.	71.9%
5. Which of the following methods do you consider most effective to ensure the implementation of sustainability into the architectural design process?	
Answer	Ratio
Empirical methods.	3.7%
Systematic methods with theoretical foundations adapted to architectural design process.	49.3%
Sustainability commercial evaluation systems (i.e., LiderA, LEED, BREEAM, CASBEE).	13.8%
I do not know.	31.8%
Other method.	1.4%
6. Please add any comments on what you consider necessary for developing guidelines to a sustainable project.	
Answer	Ratio
Open answers	97.0%

Appendix B

Table A2. Levels of Recommendations for Guidelines for a sustainable project.

Levels of Recommendations
Is recommended
Should be considered
May be considered

TABLE A. PROGRAM AND DATA COLLECTION	LEVEL
PASSIVE STRATEGIES	
a. Site and Climate	
> Analysis of environmental characteristics of the site and possibility of bioclimatic solutions.	
<div>Additional Specifications</div> <p>The following parameters should be considered:</p> <ul style="list-style-type: none"> - topography; - solar geometry, angle and intensity of solar radiation; - prevailing winds and breezes; - air movements; - humidity and air pressure; - range of temperatures; - levels of precipitation and snow; - soil type; - daylight availability; - effect of daylight obstructions; - outdoor air quality; - noise levels; - availability of recyclable materials taken from demolition or site stripping; - identification of pollution or contamination sources such as radon gas. 	
> Definition of energy efficiency strategies according to the climatic context.	
> Use of analysis techniques (e.g., sundials, sun path diagrams, wind maps, bioclimatic charts) to collect and study relevant data.	
b. Urban Context and Conditions	
> Analysis of the possibility of implementing harvesting and wastewater recycling systems.	
> Analysis of the availability of local renewable resources to produce electricity.	
> Analysis of the most appropriate solutions to generate or dissipate heat .	
> Analysis of water and heat storage solutions.	
c. Adapting the Program to the Site	
> Adapting the program to the site to reduce impermeabilized areas and minimize natural resources consumption.	
<div>Additional Specifications</div> <p>The following parameters should be considered:</p> <ul style="list-style-type: none"> -profile of users; -number of users; -functions of the building; -typology of spaces. 	
d. Internal Consumption and Needs	
> Estimates of internal consumption and needs .	

Additional Specifications

The following parameters should be considered:

- internal heat gains;
- electric load;
- artificial lighting needs;
- water consumption needs.

e. Other Criteria

> Analysis of other criteria including **surroundings** and **visual relations; social, historical and economic context**.

Additional Specifications

The following parameters should be considered:

- social and historical context;
- economic context;
- identification of protected areas or elements;
- integration in the urban structure;
- accessibilities;
- visual relations.

TABLE B. FEASIBILITY STUDY	LEVEL
PASSIVE STRATEGIES	
a. Siting	
> Site plan should be designed to balance terrain cut and filled to reduce the need for imported or exported soil from the site and not to damage the soil structure.	
> Positioning the building to fit the existing topography, soil, vegetation and drainage context to minimize soil erosion and preserve natural ecosystems.	
> Positioning the building to avoid unnecessary overshadowing of one building by another.	
> The proximity of the proposal to existing buildings should be considered according to thermal needs .	
<p style="text-align: right;">Additional Specifications</p> <p>Building contact with adjacent constructions should be considered to increase thermal inertia and minimize heat dissipation; alternatively, it should be avoided to preserve access to breezes of each building.</p>	
b. Orientation	
> Orienting the building according to the geometry of the sun .	
<p style="text-align: right;">Additional Specifications</p> <p>In the northern hemisphere, the longest axis of the building should match the east-west axis facing the solar wall directly to the south.</p>	
> Orienting the building according to prevailing winds and cool breezes .	
<p style="text-align: right;">Additional Specifications</p> <p>If the effects of prevailing winds are undesirable, the longest axis of the building should be parallel or with a slight angle to predominant winds to protect it from severe air movements. If the effects of prevailing winds and cool breezes are beneficial to promote natural ventilation, the longest axis of the building should be perpendicular to air movements.</p>	
If the two guidelines above reveal to be contradictory, a reasonable compromise should be made by adopting other possible strategies to meet daylight and thermal needs.	
c. Form	
> An east-west , in the northern hemisphere, longitudinal and compact form of the building is favourable to reduce heat transfer and maximize sunlight.	
> The form of the building should be suitable to mitigate predominant wind loads , mainly in very tall buildings , and allow the building's access to cool breezes for natural ventilation .	
<p style="text-align: right;">Additional Specifications</p> <p>Rounded aerodynamic profiles, angled to prevailing winds or with its narrowest face turned to the wind, may be considered for tall buildings.</p> <p>Gradual transitions of building height, sloped in the direction of prevailing winds, may be considered to minimize strong wind movements.</p> <p>The building form should avoid wind turbulence effects at ground level and building's entrances should be protected from wind pressure.</p>	
> The form of the building can be favourable for outdoor noise control .	

Additional Specifications

A closed form, transitional areas between the exterior and the interior of the building or the introduction of a physical barrier between the noise source and the building are example of strategies that can reduce the level of outdoor noise entering the building.

d. Envelope

> The **roof's shape** must be appropriate to regional climate conditions.

Additional Specifications

Flat roofs are appropriate for regions with a low precipitation levels while pitched roofs are appropriate for regions with high precipitation levels or snow.

> Definition of **glazing area** according to the **solar orientation** of each façade.

> Adoption of passive **shading systems** for solar protection.

> check guidelines III. d.

> Minimization of **building's skin area** (walls and roof) to **minimize heat transfer**.

e. Landscape

> Implementation of **green roofs** to collect water and increase thermal performance.

> Implementation of the most appropriate **height, density of foliage** and **spacing** between vegetation.

> Use of existing and **native species** to preserve natural ecosystems.

> Planting vegetation to **avoid overheating** of spaces exposed to excessive solar heat gains during warm periods.

Additional Specifications

Deciduous plantation provides shade during the summer and allows insolation during the winter.

Coniferous plantation provides shade year-round.

> Planting vegetation to **reduce prevailing winds' velocity** and allow cool breezes to pass through natural ventilation.

> Plantation of tall and dense vegetation can **reduce sound propagation** into the interior of the building.

> **Large bodies of water** or **water features** can be used to moderate temperature range through **evaporative cooling**.

Additional Specifications

Still water should be avoided as it can become a breeding ground for insects and microorganisms (such as legionella) that can be dangerous to human health.

TABLE C. PRELIMINARY DESIGN	LEVEL
PASSIVE STRATEGIES	
a. Structure	
> The building design should be compatible with a structure that is resistant to natural hazards to assure mechanical resistance and stability.	
> A structure with an adaptable layout promotes flexibility to the spaces , facilitating the future reuse of the building and its adaptation to new functions .	
b. Internal Layout	
> Spaces should be arranged within the building according to daylight and temperature requirements .	
<p style="text-align: right;">Additional Specifications</p> <p>Rooms with specific functions should be located adjacent to the most appropriate facades according to solar geometry. Clustering rooms reduce skin area and thus, heat gains. Rooms can be distributed vertically within buildings to benefit from temperature stratification.</p>	
> Dimensioning rooms according to function of the building and number of users , avoid unoccupied spaces or areas greater than required.	
<p style="text-align: right;">Additional Specifications</p> <p>Thin plan room arrangements, with a depth of less than 2.5 times the window height, ensure a minimum level and uniform distribution of daylight throughout the space and reduces heat dissipation.</p>	
> Dividing the building into thermal zones with buffer areas (e.g., sunspaces, courtyard, atrium, balconies) that can receive temperature swings and protect rooms from undesirable heat or heat dissipation.	
<p style="text-align: right;">Additional Specifications</p> <p>Sunspaces in cold climates can retain solar heat gain and distribute it to other spaces. Courtyards and atrium can receive sun light for heating or cooling purposes. Balconies can be considered at south and west-facing windows, in northern latitudes, to prevent overheating and, at the same time, function as a shading element for windows below.</p>	
> Areas with special air quality needs (e.g., bathrooms, kitchens, garbage rooms) should be separated from other living spaces so that pollutants generated in those areas would not mix with air with better quality.	
> Internal layout should be adapted to control noise inside the building .	
<p style="text-align: right;">Additional Specifications</p> <p>The overall size and volume of rooms should be adapted to acoustic requirements, particularly spaces with specific functions such as classrooms, offices, concert halls, etc. Rooms can be arranged within the building so that noisy areas are not located close to areas that require users' focused attention.</p>	
c. Opening Elements	
> Opening elements should be planned (dimensions, exposure angle and arrangement on the façade) according to the activities taking place, size of the room and number of occupants to match daylight needs and ventilation loads .	
<p style="text-align: right;">Additional Specifications</p> <p>South-facing windows in the northern hemisphere provide maximum solar gains. Opening elements can be planned to provide different light effects through direct or diffuse light. Vertical windows are advisable for admitting low-level sunlight in winter and promoting natural ventilation. The minimum area of opening elements should be about 5% of floor area to admit the most appropriate ventilation load. Large openings of equal size placed opposite to each other increases the effect of cross ventilation. A considerable distance between high and low openings increases the effect of stack ventilation.</p>	

> **Glare** inside rooms **should be avoided**.

Additional Specifications

A window splay can be considered to reduce glare.
Direct light should be avoided in working rooms to prevent glare.

> **Main doors** should be **located away from prevailing winds**.

d. Shading Elements

> Shading elements should be planned (dimensions, exposure angle and arrangement on the façade) according to the **solar orientation of the façade** and **daylight and thermal requirements**.

Additional Specifications

Shading elements should be considered for south and west-facing windows in northern latitudes to prevent overheating.

> **External shading elements are preferable** since the sun radiation does not reach the interior of the building.

> The **most favourable type and technology** (e.g., vertical louvers, horizontal overhangs, eggcrate, screenings) of **shading devices** should be investigated.

Additional Specifications

Overhead horizontal shading elements protect from the high sun.
Vertical shading elements protect from the low sun.
Interior light shelves can be used to reflect light to the ceiling, which reduces glare and improves daylight distribution.
Shading technology that allows diffuse light inside the building while protecting from direct light can be considered.

> **Vegetation** can be used as a seasonal shading element.

> check guidelines II. e.

> **Shading systems that maintain outside views** are preferable, to allow a visual connection with the exterior world.

e. Natural Ventilation

> **Natural ventilation** should be promoted **if outside air is not polluted**.

Additional Specifications

If outside air is polluted, air filters should be considered to reduce contaminant concentrations.

> **Cross-ventilation should be ensured** and prioritized over single-sided ventilation.

Additional Specifications

To benefit from the cross-ventilation effect, the room depth should not exceed 5 times the room height.
If cross-ventilation is not possible, the room depth should be limited to about 2.5 times the room height.

> **Stack-ventilation should be considered** to promote air circulation and cooling.

Additional Specifications

An atrium, vertical towers (windcatchers), solar chimneys, single sided double-openings and cavity ventilation are examples of solutions that can increase stack-ventilation effect.

> Dimensions and arrangement of **opening elements** on the façade should **match the ventilation loads**, according to the **activities taking place, size of the room and number of occupants**.

> check guidelines III. c.

> **Night-time breezes** should be considered to cool the building during the night.

f. Additional energy efficient strategies

> **Opaque elements of the building's envelope** (roof, walls and floors) should have **high thermal storage capacity** to reduce temperature variations.

<p>Additional Specifications</p> <p>Besides thermal insulation, other passive strategies can be used for heating or cooling the building. A Trombe Wall facing south in northern latitudes can be used as a heating strategy for cold regions.</p>	
<p>> Natural thermal equalizers can be used for heating and cooling.</p>	
<p>Additional Specifications</p> <p>Passive ground-coupling or roof ponds can be used for purposes of heating and cooling air or water. Rock beds can be used for cold or heat storage.</p>	
<p>ACTIVE STRATEGIES g. Heating and Cooling Solutions</p>	
<p>> Photovoltaic panels should be considered to produce electricity for heating and cooling if the on-site sunlight exposure period is long.</p>	
<p>Additional Specifications</p> <p>Photovoltaic panels can be integrated on the façade and may also function as shading systems. Photovoltaic panels should be oriented towards the sun and should be large enough to meet the building's electric load.</p>	
<p>> If powered by renewable resources, other heating and cooling systems besides photovoltaic panels can be considered for space heating and cooling and provision of hot water.</p>	
<p>Additional Specifications</p> <p>Solar collectors can be used for space and water heating: Glazed flat-plate collectors are recommended for domestic and commercial buildings. Unglazed flat-plate collectors are recommended for swimming pools or to be used as a heat source for heat pumps since they have a low efficiency degree, which is a result of high thermal losses. Evacuated-tube collectors are the most efficient but can be costly and are therefore mostly suitable for industrial buildings. Heat exchangers can be used for heating and cooling: Air-air heat exchangers can be considered for heating, cooling and ventilation. Ground-coupling heat exchangers through boreholes or grid pipes can be used for heating or cooling. Ground or surface water exchangers can be used for heating or cooling. However, great care must be taken to avoid contaminated water or the corrosion of installation components.</p>	
<p>> Heating and cooling storage should be selected so that users' needs are fully met during the hours of higher consumption.</p>	
<p>Additional Specifications</p> <p>Short-term heating and cooling storage can be considered according to thermal requirements (e.g., small water tanks or tank in tank systems). Long-term heating and cooling storage can be considered according to thermal requirements, (e.g., large water tanks, natural or enclosed aquifers, mixture of gravel and water sealed off from the surrounding soil, ground strata connected via vertical boreholes).</p>	
<p>> Heating and cooling distribution should be selected.</p>	
<p>Additional Specifications</p> <p>Water pipes as a medium to distribute heat can be considered since water has a higher heat capacity than air.</p>	
<p>> Heating and cooling output should be chosen.</p>	
<p>Additional Specifications</p> <p>Individual components for heating (e.g., radiator, floor outlet) or cooling (e.g., ceiling outlet or long-range nozzles) can be used for space heating and cooling. Heated surfaces (e.g., underfloor heating, ceiling heating) can be used for space heating.</p>	
<p>TABLE D. DETAIL DESIGN</p>	
<p>PASSIVE STRATEGIES a. Materials Selection</p>	<p>LEVEL</p>
<p>> Materials should be recyclable and reusable.</p>	

>Whenever possible, materials should be **selected from local sources** using minimum energy in production and transport to reduce environmental impacts.

>Finishing materials should be **selected according to the activities taking place** in each room.

>Materials should be selected based on their **thermal performance**.

>check guidelines IV. b.

>**Finishing materials** can be selected according to their **colour**, lightness or darkness, depending on the climatic context.

Additional Specifications

Light-colored finishing materials, mostly appropriate for hot climates, reflect solar radiation, which means they reflect light and heat.

Dark-colored finishing materials, mostly appropriated for cold climates, absorb solar radiation, which means they absorb light and heat.

>**Porous absorbent materials** (e.g., fibrous materials, open-celled foam) or **resonance absorbent materials** can be considered for soundproofing depending on the frequency distribution of noise to be absorbed and the acoustic absorption profile required.

>Materials that contain **toxic components** (e.g., VOCs, SVOCs, radon, and others) that may represent a risk for users' health or cause polluting emissions **should not be used**.

>Exterior materials should be **resistant to temperature fluctuations, air contaminants and chemical agents** (e.g., airborne salt).

>Materials should be **protected against biological agents** that might damage materials (e.g., termites and other pests, microorganisms, plants).

>**Waterproof and moisture resistant materials** should be selected for wet areas or where condensation may occur to control moisture and prevent the growth of microorganisms.

>Materials and components of the building should be **easy to clean and maintain**.

>**Glass technology** can be selected to **balance daylighting and thermal needs**.

Additional Specifications

Glass coating technology can provide dynamic control of daylight and thermal needs (e.g., photochromic glass, thermochromic glass, electrochromic glass).

Glass technology can scatter light evenly and avoid glare, although in some cases the outside view may be lost (e.g., light-scattering glass, diffuse glass, glass blocks).

Glass technology can be selected for daylight directional control (e.g., prismatic glass, holographic glass, electrochromic glass).

b. Thermal Insulation Materials

>The **entire building envelope should be properly insulated** to reduce heat transfers and stabilize interior air temperature.

>Materials with a **lower U-value** (thermal transmittance) [W/m²K] should be selected for a better insulation performance.

>**Exterior insulation** is advisable to control the air flow within building components and prevent condensation.

Additional Specifications

A vapor barrier on the warm side of insulation is required to prevent condensation.

>A **low-E** (low emissivity) **glass with double or triple sheets** should be considered to improve thermal insulation capacity of glazing.

Additional Specifications

The spacing between each sheet of glass should not be too narrow (the insulating effect is then lost) neither too wide (a layer of condensation can be formed, and the low-emissivity coating loses effect)—15 to 20 mm is the recommended glazing spacing for thermal insulation.

Glazing sheets can be partially evacuated or filled with gas instead of air for better insulation performance.

>**Transparent insulation materials** (e.g., honeycombs) can be considered since they have a high transmission of solar radiation and good thermal qualities.

c. Construction Details

>**Multi-leaf facades** with an air layer should be considered to improve insulation.

>**Joints between different components** of the building should be **airtight to minimize thermal bridges**.

>**A drainage system** should be installed to direct rainwater away from the building.

d. Water Fixtures

>**The selection of low water flushing volume toilets and urinals and low volume taps and showerheads is recommended.**

Additional Specifications

The recommended average capacity of flushing tanks for toilets is 6, 4 or even 1 L.

The recommended water flow rate of taps and showerheads is 10L/min.

Low water flushing volume toilets include interruptible flow systems, double discharge tanks and flushing tanks with reduced capacity.

>The installation of **waterless or dry composing toilets** may be considered.

Additional Specifications

These systems require regular maintenance.

>The most favourable **type of toilet flush system** should be investigated **to reduce water consumption**.

Additional Specifications

The main types of toilet flushing systems are gravity tank, flushometer and vacuum toilets.

>**Water fixtures technology** can be used to reduce water consumption.

Additional Specifications

Aerator taps can reduce water flow but maintain water pressure.

Thermostatic taps can control water temperature and avoid excessively hot water.

Taps with solenoid valves can shut off water when not in use.

Flow rate delimiters can regulate flow rates.

e. Building Management

>**An operation and maintenance manual** with important information about the building should be provided to the users.

>**A computerized building management system** can be installed to automatically regulate energy and lighting requirements, security, lift operation and several other functions.

ACTIVE STRATEGIES

f. Low Consumption Devices

>**Energy efficient appliances** (e.g., artificial lighting, refrigerators, freezers) and equipment should be selected.

>**CFLs, LEDs or other energy saving lamps** should be selected.

>**Artificial light** should be optimized to **meet users' needs**.

Additional Specifications

Occupancy detection or time control systems should be installed to provide automatic light control.

Daylight sensors can be considered to adjust artificial light intensity according to the incoming natural luminous flux.

Artificial light control should be sectioned so that individual rows can be switched on or off as needed.

>**The type, arrangement and number of luminaires** should be appropriate to **room functions**.

Additional Specifications

Task lighting is appropriate for localized activities that require focus.
 Amenity lighting is appropriate for overall space illumination.
 Spot lighting is appropriate for punctual illumination.

>**The color of lamps** should be appropriate to **room functions**.

Additional Specifications

White-colored lamps are similar to natural daylight and should be chosen for rooms where focused attention is required.
 Warm-colored lamps should be chosen for a comfortable and relaxing atmosphere.

>**Water efficient appliances** (e.g., dishwashers, washing machines) should be installed.

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