SUSTAINABLE TECTONICS: a conceptual framework to formulate formal structure of sustainable designs.

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ABSTRACT: Sustainable architecture is a multi-disciplinary field concerned with buildings that are designed to respond to the environmental, social and economical issues as well as architectural qualities. From this article's point of view, many of so-called sustainable building designs only focus on external environmentally responsive techniques or figurative arbitrary aspects and rarely concentrate on the underlying characteristics of spatial and formal structure of architecture. The aim of current article is to highlight the generative power of architecture for providing sustainability through the modification of essential design layers derived from tectonic studies. The tectonics systematically determines the critical analytical factors which could be employed to evaluate the constitutive layers of architecture formal structure both in design and practice. In order to make the previously introduced characteristics and layers detectable in sustainable architecture design, the paper proposes a conceptual framework under the topic of Sustainable Tectonics to formulate formal structure of sustainable designs. This conceptual framework is taken from the article's theoretical framework; sustaining architecture which, itself is obtained from an inquiry on interactions between two principle headings; sustainability and architecture design through grounded theory research method founded in thematic analysis and logical argumentation, it also employs the comparative and critical analysis of selected case studies in researches and practices.

Keywords: Conceptual framework, Formal structure, Sustainable architecture, Tectonics, Sustainable Tectonics.

INTRODUCTION

Sustainable development is an increasingly relevant goal in today's architecture and urbanism, which should involve considerable change in our perspective. A sustainable architecture should answer not only to the development objectives but also to the architecture itself as a medium which can provide a great share of sustainability to our cities through specific activities.

By this preface, the problem of this article is not how to make architecture less unsafe to the environment and the human. It is, how to make architecture having the ability of contributing to the improvement of a sustainable city, both by its formal structure and generative power as Los (Los, 1998) formerly asked in the article; integration between art and science in architectural design. Here, in this research, evolution of the concept of sustainable tectonics refers to two main different but related questions; first, the interaction between sustainability as a concept and architecture design as a result, phenomenon or medium which provides the research's theoretical framework and second question refers to; how could we find a policy to formulate and analyse the formal structure¹ of architecture both in design and practice which builds the research's conceptual framework.

The on-going development of sustainability concerns specifically on environmental issues, has changed the focal points of architectural design from the construction of space and volume to the energy, economy, environment, etc. Architects are more and more confronting the design challenges to properly manipulate both architectural (material, object, surface, space, etc.) and sustainability (social, economical, economical, etc.)...
environmental, etc.) aspects, elements and systems by integration between art and technology in a hybrid design process, in conclusion, the convergence of art and technology is breeding a shift in sustainable design and practices. According to Farshid Musavi (Musavi, 2011) Let sustainability not be a safety-check on the architectural process, but a way to design. In this regard, UNStudio as an avant-garde and pioneer architecture firm has proposed a diagram for Architectural Sustainability Platform (ASP) which has been shown in Figure 1. They claim that The ASP is committed to the promotion and practice of sustainable design and different issues such as economic, social and ecological sustainability are considered from the initial stages of each project both at global and local levels (Henderson, 2013).

By Algorithmic Sustainable Design, Salingaros (salingaros, 2010) proposed an innovative framework for architecture design and re-establish adaptability and genuine sustainability. This framework applies different tools from codes and cellular automata to scaling and organization to design. Hensel & Menges (Hensel & Menges, 2006) tried to suggest a new understanding of sustainable design strategies in which the architecture system response to environmental conditions and other external forces. They really recommend a design method based on form finding through different material systems, so sustainable architecture is in a process of redefining and re-formulating the basics, principles and concepts of the design relationships as well as their prioritizing.

As a means of identifying the singularities of architecture in sustainable architecture, we introduce the term, sustaining architecture. It is the blurry and vague of sustainability that makes sustainable design a complex subject. In this novel expression- sustaining architecture- it is also the affinity between sustainability and architecture that enhances the design possibilities.

By sustaining architecture the article implies to a new theory for thematic understanding and taxonomy of sustainable design approaches based on the conceptual analysing of the related ideas about the architecture role and character in this combination.

With this shift towards a new interpretation of architecture in sustainable design, emergence of a new conceptual framework which can formulate and analyse the formal and spatial structure of architecture seems inevitable. While the paper concentrates on the formal structure of sustainable designs, a conceptual framework which is extracted from the tectonic studies has been proposed to facilitate comprehension of article’s theoretical framework through formulation of sustainable designs’ formal structure.
In the following sections we first introduce the research method. A brief review on literatures, ideas and relevant concepts is presented and discussed in second section in which a selection of case studies that illustrates principles and different models of sustainable-based design has been considered also this section reveals the theoretical framework of the article. Third section introduces the concept of sustainable tectonics and discusses its meaning, importance and factors as a tool to improve the theoretical foundation; sustaining architecture. The last section presents the description and demonstration of building a conceptual framework based on tectonic studies for analysing the formal structure of sustainable designs, including the development and taxonomy of classical factors of tectonics with regards to sustainability. Finally, summary and conclusions are discussed with respect to the two main objectives of this research: sustaining architecture and sustainable tectonics.

METHODS AND PROCEDURE

The article suggests that building a conceptual framework from gathering all needed information related to the subject of sustainable design approaches and existent multidisciplinary literature which is a process of theorization uses grounded theory methodology. In other words, first step in building of a conceptual framework is making a theory based on data and extracted codes from previous researches and comparative approach in different cases necessitate applying ‘grounded theory’ in this research. Grounded theory is adequate for conceptual framework building due to its primary characteristics. It is a specific paradigm of inquiry that includes a number of distinct features and involves the use of coding paradigms to ensure conceptual development (Strauss, 1987). It is a research method aimed at the discovery of theory from systematically obtained data and “an inductive, theory discovery methodology, which facilitates the generation of theories of process, sequence, and change pertaining to organizations, positions, and social interaction” (Jabareen, 2009, p.52).

Therefore to build a conceptual framework the paper firstly lights on a theoretical framework by categorizing various approaches in sustainable architecture and design among the possible fields and tendencies via contiguously analysing of related ideas, concepts and practices till main items for proving a theory was extracted, next the conceptual framework has been built to analyse the formal structure of architecture design in the case of sustainability, derived from tectonic studies. This conceptual framework has been taken from classification of tectonic factors in three different categories: Factors, Major Factors, Structure. The proposed methodology is composed of the following main steps:

Representing the selected data sources
The first step is to represent the spectrum of multidisciplinary literature regarding the question of the research. This process includes identifying text types and other sources of data, such as existing practices. Here the article depicts two different sources which directly or indirectly implies to the sustainable designs and practices; first, extracted texts from related literatures of the sustainable design strategies and second, case studies including built or unbuilt projects under the title of sustainable design and same scales. Therefore in addition to literature review, the method of observation and constant comparison between them was applied for more than 50 projects including 19 proposed projects of solar decathlon 2013 competition, 20 projects of Expo Milan 2015 and 12 random projects. The reason of choosing these spectrums of texts and projects refers to their main concept; sustainability with concentration on environmental aspects, also scale of projects has been considered.

Deep reading and categorizing of the selected data
The purpose of this step is to read the selected data, and categorize it both by discipline, theme and concept.

Identifying, naming and categorizing the concepts
The aim of this step is to discover concepts. This method allows concepts to emerge from the literature or coded data collected from constant comparison of case studies. Its result is a list of competing or even contradictory concepts. Also to identify the main attributes, characteristics, assumptions and subsequently, to categorize the concepts according to their features, main Ideas, themes and methodology, this step has been considered.

Integrating concepts
The purpose of this step is to integrate and group together concepts that have similarities to one new concept. This new concept should encompass the main idea of the previous concepts.
**Synthesize concepts into a theoretical framework**

Emerging a new theory through the repetitive synthesizing and resynthesizing theorization until the researcher recognizes a general theoretical framework that makes sense is what happens in this step.

**Building a conceptual framework**

A researcher may opine that his/her research problem cannot meaningfully be researched in reference to only one theory, or concepts resident within one theory. In such cases, the researcher may have to “synthesize” the existing views in the literature concerning a given situation – both theoretical and from empirical findings. The synthesis may be called a model or conceptual framework, which essentially represents an “integrated” way of looking at the problem (Imenda, 2014).

To formulate formal structure of sustainable designs, the paper proposes a conceptual framework which is taken from the combination between theoretical framework driven from step number 6 and tectonic studies which provide us general evaluation factors in architecture. Finally the result would be a series of specific tectonic factors for sustainable architecture formal analysis. Data reduction, and the drawing and verification of conclusions will be ended in a conceptual framework.

**Theoretical Framework: Sustaining Architecture**

A theoretical framework refers to the theory that a researcher chooses to guide him/her in his/her research. Thus, a theoretical framework is the application of a theory, or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or shed some light on a particular phenomenon or research problem (Imenda, p.189, 2014).

Construction of a theory in sustainable design which concentrates on the underlying characteristics of spatial and formal structure of architecture versus many of so-called sustainable building designs which only focus on external environmentally responsive techniques attachments or figurative arbitrary aspects was one of the main objectives of this article. This theory under the topic of sustaining architecture based on Integration between art and technology in sustainable design has been chosen to build a theoretical framework to guide the research. Sustaining architecture as a theory insists on the medium role of architecture in which the concept of sustainability caused changes in architecture itself to convey the idea of sustainability.

Contemporary conversations about sustainability and ecological considerations with respect to architecturally related areas are based on the idea of sustainable development, outlined by the Brundtland Commission in 1987: that the needs of the present society should be met without compromising the ability of future generations to fulfil their own needs (Junjie Xi, p. 287, 2013).

According to the Metapolis dictionary of advanced architecture the concept of sustainability in construction will lead us to conceive a building as an act which doesn’t start with delivery of materials to the site and end when inhabitants move in (cros, 2003).

As it was mentioned, from the article’s perspective, many of named sustainable building designs only focus on external techniques attachments or formal aspects and hardly concentrate on the fundamental layers of spatial and formal structure of architecture. According to Mehaffy & Salingaros (Mehaffy & Salingaros, 2013) “something surprising has happened with many so-called “sustainable” buildings. They’ve proven far less sustainable than their proponents have claimed. In some cases they’ve actually performed worse than much older buildings, with no such claims. What’s going on with these supposedly “sustainable” buildings?”

The research’s problem refers to the idea that buildings usually ask for sustainability through the superficial green attachments such as more efficient mechanical equipments, also there are lots of buildings that figuratively showing off sustainability concerns instead of questioning the deep-rooted architecture layers like design concepts or formal and spatial structures.

The results of research method from steps 4 and 5 of shows that present tendencies and concepts in sustainable architecture design could be categorized into two main groups which have been shown in Table1.

<table>
<thead>
<tr>
<th>Idea</th>
<th>Purpose</th>
<th>Promoting Tools</th>
<th>Architecture Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability</td>
<td>in</td>
<td>- Performance Promoting</td>
<td>- Correction</td>
</tr>
<tr>
<td>architecture</td>
<td></td>
<td>- Architecture Promoting</td>
<td>- Corrective architecture</td>
</tr>
</tbody>
</table>

Our objective is a sustainable architecture. This may be characterized in many different ways. Here, however, we would expect such architecture to be performative, that is, capable of providing occupant comfort at lowest carbon emission; and, expressive, that is to reflect the architectural programme and its context in terms of climate, site and culture(Yannas, 2005).

From this view and from extracted results of Table1, the article divides current sustainable architecture approaches into two main categories based on their ground states and theoretical frameworks:
Sustainability Precedence (SP): this approach refers to the group of architects and practitioners’ idea who search for sustainability goals or performance promoting through correction tools same as external means or attachments in architecture. A movement which emphasizes on sustainability even they can find it or not (Figure3).

![Figure3. Sustainability Precedent (SP) in sustainable design (URL).](URL)

Architecture Precedence (AP): this approach refers to the group of architects and practitioners’ idea who search for architecture alteration and promotion through the generative tools in sustainability. A movement which emphasizes on architecture (Figure4).

![Figure 4. Architecture Precedent (AP) in sustainable architecture (URL).](URL)

To remain consistent in conception of architecture as a medium which can make sustainability available while its essence has considered throughout the process of design and practice, the paper discovered a third approach:

Integration Precedence (IP): this approach refers to the idea of sustaining architecture; emphasising on moderate role of architecture in sustainability achievements through the architectural responsive reactions. Surely this response would not be a technical-mechanical attachment (SP) or a superficial architecture layer with no proven application and performance (AP), it profoundly implies to the deep constitutional parameters of architecture modifications through a generative process in which the sustainability idea has been conveyed (Figure5).

![Figure5. Integration Precedent (IP) in sustainable architecture (Yannas, 2005, Hensel& Menges, 2006. URL)](URL)
The article’s theoretical framework has been established on the recent approach (IP) under the topic of sustaining architecture in which architectural composition or building parameters organization would change based on the architecture task for providing sustainability goals while this change is not only about an optional arbitrary alteration even it is about a complementary relationship between architecture and sustainability in different levels and discourses which could be emerged through a process of integration between art and technology in architecture. Using guidelines presented in method and procedure section, above materials could be summarized in the subsequent Table2.

Table2. Summery and results of concept categorizing in sustainable design based on thematic analysis.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Main themes</th>
<th>Case studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability Precedent (SP)</td>
<td>- Energy efficiency</td>
<td>- Solar decathlon competition projects and practices</td>
</tr>
<tr>
<td></td>
<td>- Environmental issues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Comfort</td>
<td>- Renovated projects</td>
</tr>
<tr>
<td>Promoting sustainability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture Precedent (AP)</td>
<td>- Feeding the Planet</td>
<td>- Expo 2015 Milan</td>
</tr>
<tr>
<td>Promoting architecture</td>
<td>- Energy for Life</td>
<td>- Figurative parametric-algorithmic architecture</td>
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<tr>
<td></td>
<td>- Technology for Agriculture and</td>
<td></td>
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<td></td>
<td>- Food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- arbitrary Parametricism and complex geometry</td>
<td></td>
</tr>
<tr>
<td>Integration Precedent (IP)</td>
<td>- Moderate role of architecture</td>
<td>- EM-Tech projects</td>
</tr>
<tr>
<td>Integration between sustainability and architecture</td>
<td>- Optimizing Algorithms</td>
<td>- Vernacular Projects</td>
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<tr>
<td></td>
<td>- Form-finding</td>
<td>- Environmentally responsive architecture practices</td>
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<tr>
<td></td>
<td>- Interactions</td>
<td></td>
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<tr>
<td></td>
<td>- Performance Oriented</td>
<td>- Para-Algorithmic sustainable designs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Bio architecture</td>
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</table>

From Sustaining Architecture To Sustainable Tectonics

In attempting to address the objectives of this study a closer look at the procedure of the research evolution is essential. As it was alluded before, the main purpose of current article is to highlight the generative power of architecture for providing sustainability through the modification of essential design layers. In this regard the paper firstly tries to establish a theory of interactions between sustainability (as a leading concept) and architecture (as a medium which can convey the sustainability idea) that finally ended in “sustaining architecture” theory. According to Liehr and Smith (Liehr & Smith, 1999) a theory is like a blueprint, a guide for modelling a structure, its elements and their relations. To represents an integrated way of looking at the problem, the next step would be finding a conceptual model or a conceptual framework fundamentally based on the mentioned theory, extracted from a synthesized process which can help the researcher to analyse and formulate the essential design layers.

While the focal point of this research refers to the formal structure and building skins in sustainable designs, it suggests a conceptual framework stands on tectonic studies to decipher if any conceptual relationship exists among the formal layers and sustainability idea.

The development of tectonic studies is enabling a new analytical platform for sustainable design collaboration with a growing inter-relationship between art and technology. We are currently witnessing a transition within the sustainable design process. The growing harmony between the interest in the role of sustainability in design and in the relationship to formal structure has produced a “new tectonics” which has been called “sustainable tectonics” in this article.

The emerging new synthesis of formal structure in design is resulting in the formulation of conceptual principles of the sustaining architecture in new tectonic orders. Furthermore, the logic of these tectonical and formal principles is becoming integrated within the rationale of emerging green technologies, thus enriching the possibility of the potential integration of design with art and technology.

Tectonics

Tectonic is becoming a pioneer concept in different design disciplines. This inquiry searches for benefits of tectonics in sustainable design discourse. The term tectonic, originally derived from the Greek word, tekton, means carpenter or builder.

Tectonic means in Cornell’s definition “clearly built with constructive or building elements and parts, either they are necessary or only figurative” (Nilsson, 2007). The phrase tectonics also implies to process of creation referring to the creation of artistic works. This included the aspects of skill, method, material and even concept (Liu & Lim, 2005).

The concept of tectonics has a long history in architecture. In different periods, tectonic discourse has continually redefined its elements and their relationships. Historic usage adapted tectonics to transform the
concept from that of the builder to that of an integrated building system (Semper's theory). According to the Frampton's interpretation of tectonics; “poetics of construction”, the ordering of architecture, structure, material and construction evolved from aesthetic and cultural statements of expressive qualities (Oxman, 2012).

As it was pointed, throughout the history of architecture, emphasis on tectonics principles has been changed from the pure structure issues into cultural and even digital subjects. Depending on the main concern of the research; sustainability and architecture, this paper offers a conceptual framework under the topic of sustainable tectonics as a subdivision of tectonics discourse to extract influential parameters for analyzing the formal structure of sustainable designs and buildings via the tectonics parameters.

The next section of this research discusses classical factors of tectonics to see if these elements can be used as analytical factors in processes of building a conceptual framework base on the dimensions of sustainability in one hand and tectonic factors in other hand.

**Tectonic’s Classical Factors**

According to the researches on classical factors of tectonics (Frampton, 1995; Gao, 2004; Liu&Lim, 2005), they could be defined as the following list:

1. Joint
2. Detail
3. Material
4. Object
5. Structure
6. Construction.
7. Interaction

It should be considered that from the article’s view, these factors which have been extracted from the most influential theories by widely-known theoreticians and practitioners (Botticher, 1852; Semper, 1951; Sekler, 1965; Gregotti, 1983; Frascari, 1983; Moneo, 1988; Vallhonrat, 1988; Frampton, 1995) could be employed to define the formal structure of architectural designs and buildings in the case of sustainable design. So this study attempts to extent the tectonics literature into the sustainable design discourse by utilizing and categorizing these factors.

**Building A Conceptual Framework: Sustainable Tectonics**

To feature the generative power of architecture in formulation of essential design layers with regards to sustainability, the paper proposes a conceptual framework driven from tectonic studies. As previously introduced, the tectonics systematically determines the critical analytical factors which could be utilized to evaluate the constitutive layers of architecture formal structure (Figure 6), whether they are adjusted to the sustaining architecture basics, principles and concepts or not. This conceptual framework which is taken from the article’s theoretical framework, entitled to sustainable tectonics.

![Figure6. Formal structure based on tectonic factors relationships.](image)
Simply, sustainable tectonics tries to formulate formal structure of sustainable designs by employment of tectonic factors to explore how joints, details, materials and other factors have contributed in various dimensions of sustainability. This framework emphasises on moderate role of architecture and its elements in sustainability achievements through the architectural responsive reactions (Figure 7).

**CONCLUSION**

This article pursued two main objectives:

Construction of a theory in sustainable design which concentrates on the underlying characteristics of spatial and formal structure of architecture versus many of so-called sustainable building designs which only focus on external environmentally responsive techniques attachments or figurative arbitrary aspects. This theory under the topic of sustaining architecture insists on integration between art and technology in sustainable architecture and has been chosen to build a theoretical framework to guide the research.

Building a new conceptual framework for analysing and formulation of sustainable designs formal structures and building skins. The mentioned conceptual framework under the topic of sustainable tectonics, itself, established on the basics, concepts and principles of the research’s theoretical framework which seeks for interaction between architecture and sustainability.
The results show that first objective has been achieved through the grounded theory research method, by constant analysis of extracted data from different sources, disciplines and discourses. The article also reveals a new tectonic model and framework to formulate various sustainable designs and practices through the classical tectonic factors. This model could be employed to analyse and understanding formal structure or building skins in sustainable designs.

REFERENCES


Biem, A. & others. 2013. TOWARDS A TECTONIC SUSTAINABLE BUILDING PRACTICE, The Royal Danish Academy of Fine Arts, School of Architecture, Aarhus School of Architecture, The Danish Building Research Institute, Aalborg University.


