Conceptual Design Framework for Sustainable Structures

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Abstract

This paper presents an overview of philosophical underpinnings of the discourse of sustainable structures. The world view that have been influenced by the scientific revolution occurred in modern era considers reality as a single external objective entity and hence sustainability is viewed from an objective angle. Accordingly the discourse of sustainable structures revolved around resource efficiency, new technologies, etc., but do not traverse much through other forms of realities, namely, subjective reality and inter-subjective reality such as aesthetic sustainability. Post-modernism that emerged as a reaction to modernism recognises other forms of realities as well. However, even within post-modern discourse other forms of realities are not recognised in a total integrated way. In the dawn of the new millennium, Post-postmodern era has begun, and it not only recognises multiple realities, but also integrates those realities in a complementary way. Within the Post-postmodern movement, American Philosopher Ken Wilber is a leading figure who introduced 'Integral Theory' and 'All Quadrants All Levels Framework' (AQAL Framework). This paper explores the possibility of employing the AQAL general framework for sustainable structures to develop a more specific framework that integrates many aspects of sustainability such as material sustainability and aesthetic sustainability. The paper will present how the developed AQAL framework can be used for brain storming during the conceptual design stage of civil engineering structures.

Key words: Sustainable Structures, Modernism, Post-modernism, Post-postmodernism, AQAL Framework

1.0 Introduction

The discourse of 'sustainability' and 'sustainable structures' has traversed through modern and post-modern era and now entered to the 'post-post-modern era'. During its journey, the discourse has been influenced by contemporary philosophical paradigms. In search of present and future objectives of the discourse of sustainable structures, it is useful to understand how those philosophical paradigms had influenced the discourse.

It is important to understand the use of the Latin term ‘post’ (means ‘after’) in this context. It does not mean that the post-modern era had begun after the death of modern era. It only means modern era has begun first, and after some time post-modern era has begun, while modern era continues. Accordingly, modernism emerged first and after some time post-modernism emerged, while modernism continues. Similarly, after some time Post-post modernism emerged, but modernism as well as post-modernism are still alive and continue.

Modernism and Discourse of Sustainable Structures

During the modern era the most dominant philosophical paradigm was 'positivism', hence sometimes the term 'modernism' implies positivist paradigm. According to positivism, there is one and only one reality, which is external, objective and material. Therefore, reality is reduced to quantitative, testable and objective knowledge (Harold et al, 1995). Within the positivist paradigm there is no room for qualitative, non-testable and subjective entities. Positivism had a great influence on modern science and technology. Modern science assumed that the 'reality is out there and observations of reality are independent of the observer'. As a result, science and technology was practiced considering objective and material aspects. Accordingly, the discourse of sustainable structures mainly focused on the consumption of physical and quantifiable matters, such as resources and energy, which are external, objective and material aspects.

Post-modernism and Discourse of Sustainable Structures

The basic assumption of modern science was shaken when the eminent Quantum Physicist Werner Heisenberg proved that the observations were not independent of the observer (Huckle and Martin, 2001; Crotty, 1998). After that, the so called 'objectivity' of science had fallen into a crisis. Modern world view (positivist world view) of 'single, objective reality' had been challenged. Michel Foucault explored the power-related component of knowledge creation that marginalises non-dominant discourses (Huckle and Martin, 2001). Jacques Derrida introduced strategy of 'Deconstruction' that can be employed to reveal multiple meanings (Robinson and Groves, 1998). Finally, as a reaction to modern movement, Post-modernism emerged in the latter part of the last century, and it rejects all fundamental principles of modernism (Huckle and Martin, 2001; Crotty, 1998). It rejects the modern world view of single, objective reality and recognized multiple realities. Accordingly the discourse of sustainable structures which was limited to 'objective reality' in the modern era has traversed to many other subjective or constructed realities. Discourse of sustainable structures related to biophysical systems, ecological systems, social systems, aesthetics etc., may be a result of that.

Post-post-modernism and Discourse of Sustainable Structures

Post-modernism de-constructed the grand narrative or single reality of modernism and provided a room for multiple realities. However, the stand of the 'rejection of grand narratives' prevents the integration of multi-narratives to form a meaningful whole. In this background, in the dawn of the new millennium, Post-post-modernism emerged from the post-modernism. 'Integralism' or 'Integral Theory', which was introduced by American Philosopher Ken Wilber in late 1990s, is one of the major philosophical paradigms emerged in Post-post-modern era. Integral Theory not only recognizes multiple realities, but also integrates those realities in a complementary way. It integrates all four types of realities, namely, subjective, inter-subjective, objective, and inter-objective realities. Accordingly, in this context, the discourse of sustainable structures integrates science, technology, natural systems, environment, social systems, cultures, aesthetics, individual consciousness, and all relevant aspects.

Overview of Integral Theory

According to the Integral Theory, any issue is linked to the four irreducible realities, which are subjective realities, inter-subjective realities, objective realities, and inter-objective realities. These realities can be assigned to the matrix of four quadrants as shown in Fig. 1 (Wilber, 1996; Esbjorn-Hargens, 2009).

	INTERIOR (Subjective)	EXTERIOR (Objective)
INDIVIDUAL	**Upper Left [UL]** Subjective Realities	**Upper Right [UR]** Objective Realities
COLLECTIVE	Inter-subjective Realities **Lowe Left [LL]**	Inter-objective Realities **Lower Right [LR]**

Fig. 1: The Four Quadrants

The four quadrant matrix can be expanded into a more comprehensive model, by including all development levels, lines, states and types and it is often referred as 'All Quadrants All Levels Model', or AQAL Model (De Kay, 2011). It is assumed that using AQAL Model, any issue can be understood completely, without leaving out any part.

Employing Integral Theory for Sustainable Design

Integral sustainability represents not only technological sustainability but also experiential sustainability, cultural sustainability, and systems sustainability. Mark De Kay has done a pioneering work by applying Integral Theory for sustainable design in the domain of Architecture. He employs quadrant model for sustainable design (De Kay, 2011).

All-Quadrant Sustainability

Accordingly 'All-Quadrant Sustainability' can be illustrated as in Fig. 2 (De Kay, 2011).

[UL] Subjective Realities (E.g.-Sustainability Consciousness)	**[UR]** Objective Realities (E.g.-Technological Sustainability)
Inter-subjective Realities (E.g.-Culture of Sustainability) **[LL]**	Inter-objective Realities (E.g.-Ecological Sustainability) **[LR]**

Fig. 2: All-Quadrant Sustainability

Flatland Sustainability

Most high performance design approaches collapses the reality into the upper right quadrant and green or ecological approaches collapses the reality into the lower right quadrant, or the right side of the four quadrant matrix (De Kay, 2011). When one reality is collapsed into another reality, the dimension associated with that quadrant cannot be seen, and hence it is called 'flat land' view (Fig. 3).

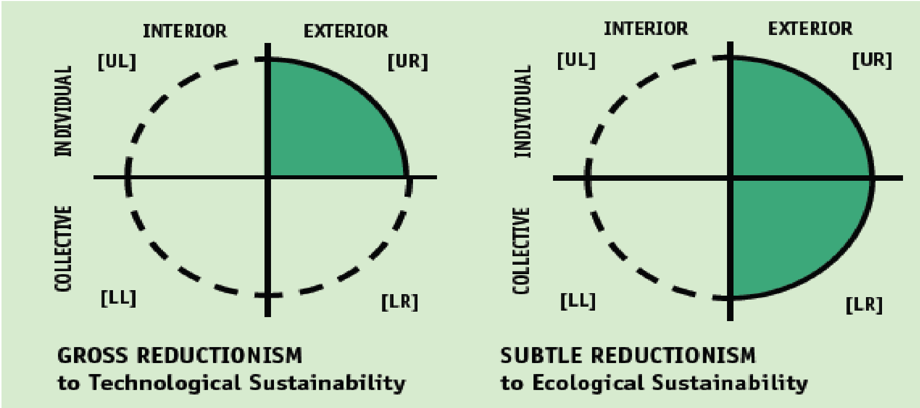

Fig. 3: Flatland Sustainability (De Kay, 2011)

It can be considered that within the modern movement, the discourse of sustainable structures is focused on the upper right quadrant or on the technological sustainability. Accordingly, the discourse concentrated on reducing the consumption of natural resources and energy, reducing waste products and pollutants emitted to nature, etc. Within the post-modern movement the discourse of sustainability took place in other quadrants, in which eco systems, environmental aesthetics, environmental ethics have been discussed. However, these discussions took place within the domains of various social/professional groups in a fragmented way. As a result, the discourse of sustainability too reflects this fragmentation. In this background, De Kay introduces a map for All-Quadrants sustainable Design, which integrates all quadrants, and it is shown in Fig. 4 (De Kay, 2011).

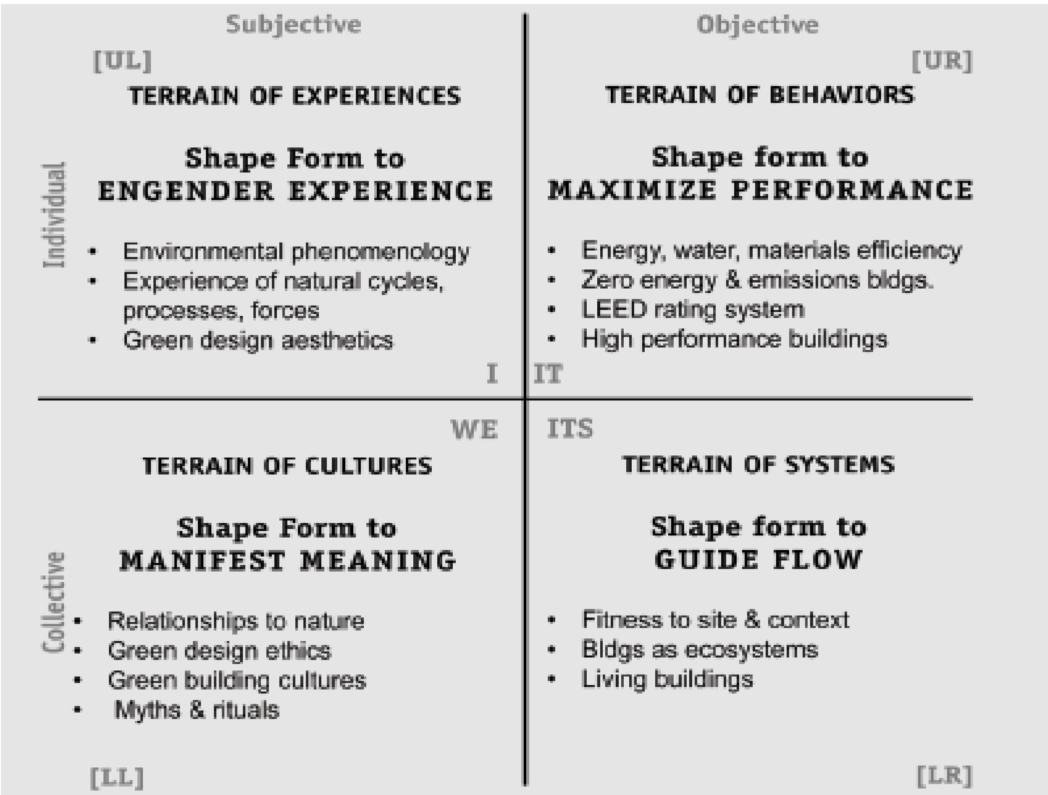

Fig. 4: Four Terrains of Sustainable Design (De Kay, 2006)

2.0 Objective and Methodology

The main objective of this study is to develop a conceptual design framework for sustainable structures to be used for brain storming during the conceptual design stage of civil engineering structures. To achieve this objective, the 'method of synthesis' was adopted. Accordingly, the 'concept of AQAL framework' for integral sustainability, and 'the concept of objective tree' from conceptual engineering design strategies were synthesised to develop a conceptual design framework for sustainable structures.

3.0 Development of the Conceptual Design Framework for Sustainable Structures

As the starting point, 'AQAL modal for integral sustainability' (De Kay, 2011), and the 'objective tree for conceptual design' (Dym and Little, 2004) were combined. According to the integral theory, a structure will be truly sustainable, only if it is sustainable with respect to all four quadrants. Structure must be subjectively, inter-subjectively, objectively, inter-objectively sustainable. Hence the main objective should be decomposed into four main sub-objectives, and each of these four sub-objectives will be further decomposed, and the process continues until the designer can not define any further sub-objectives of the parental objective. The structure of an objective tree can be presented as shown in Fig. 5.

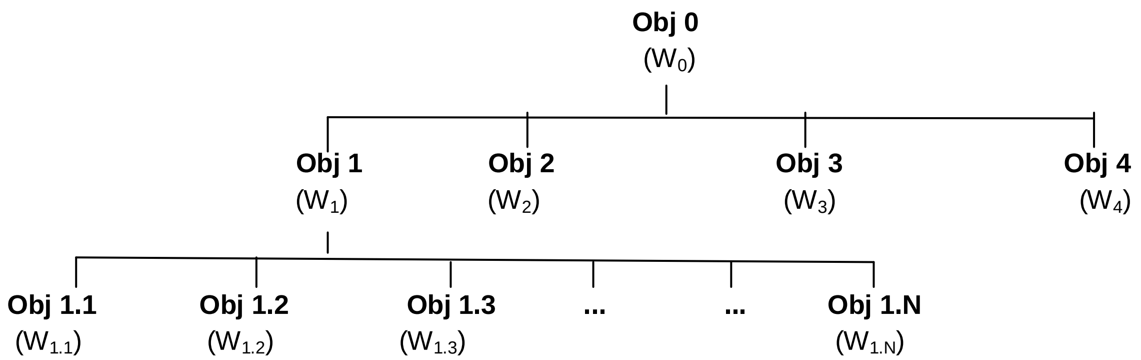

Fig. 5 : Objective Tree

The weight of the main objective (Obj 0) is considered as 1.00, and it is divided among its four sub-objectives considering their relative importance subjected to designer's judgement. Then the weights of each sub-objective are divided among its sub-sub-objectives, and so on. Accordingly, the summation of the weights of all the sub-objectives is equal to the weight of the parental objective of a particular cluster. In other words, the designer starts assigning 1.0 to the main objective and move towards the ends of the branches of the objective tree by distributing the weights among the branches.

Evaluating Alternative Design Solutions

Normally for a design problem there can be many solutions. In selecting the best design solution, it is necessary to evaluate and compare all alternative conceptual design solutions perceived and developed by the designer. This section explains how to arrive at the best design solution based on the constructed objective tree.

The scores out of hundred (S) are given to design objectives based on how well each of the design objectives can be achieved by a particular solution. These scores are approximate values decided by the designer based on thumb rules and experience. The entity W*S represent the 'weighted scores' of design objectives for a given design solution. Firstly scores of the objectives of the branches are assessed and the scores of the parental goals are computed as demonstrated in Fig. 6. This process is continued and finally the score of the root goal is assessed, and it is the score of the design solution. Scores of different alternatives are compared to choose the best design solution.

Obj A
(W_A)
S_A

	Obj A1	**Obj A2**	**Obj A3**	**Obj A4**
Weights:	W_{A1}	W_{A2}	W_{A3}	W_{A4}
Given Scores:	S_{A1}	S_{A2}	S_{A3}	S_{A4}
Weighted Scores	$W_{A1}*S_{A1}$	$W_{A2}*S_{A2}$	$W_{A3}*S_{A3}$	$W_{A4}*S_{A4}$

⇨ Score of ***Obj A*** $(S_A) = (W_{A1}*S_{A1} + W_{A2}*S_{A2} + W_{A3}*S_{A3} + W_{A4}*S_{A4}) / W_A$

Fig. 6: Relationship between scores of a Cluster

In Fig. 6 W_{A1},W_A,W_{A3},W_{A4} are the weights of objectives Obj A1, Obj A2, Obj A3 and ObjA4. The Scores given to them are S_{A1} ,S_{A2} ,S_{A3} and S_{A4}. Dividing the summation of weighted scores of sub-objectives by the weight of the parental goal, the score of the parental goal (S_A) is computed.

4.0 Application of the Conceptual Framework for Sustainable Structures

To illustrate the construction of the objective tree, an example of a bridge design is presented in this section.

Bridge Design Example

Obj 0 ***:*** *Integrally Sustainable Bridge*

Level 1 Objectives

The main objective is decomposed into the four quadratic perspectives of the AQAL Framework.

From Upper Right Quadrant => ***Obj 1:*** *Bridge should be objectively sustainable*
From Lower Right Quadrant => ***Obj 2:*** *Bridge should be Inter-Objectively sustainable*
From Upper Left Quadrant => ***Obj 3:*** *Bridge should be subjectively sustainable*
From Lower Left Quadrant => ***Obj 4:*** *Bridge should be Inter-Subjectively sustainable*

Level 2 Objectives

Level 2 objectives, which are sub-objectives of level 1, are identified by decomposing Level 1 objectives. That is Level 2 objectives are determined by decomposing ***Obj1, Obj 2, Obj 3*** and ***Obj 4***.

Objective 1 (Bridge should be objectively sustainable) can be decomposed as below.

Obj 1.1 : *be constructible with sustainable materials*

Obj 1.2 : *be constructible with sustainable structural systems*
Obj 1.3 : *be constructible/ maintainable using sustainable energy*

Objective 2 (Bridge should be Inter-Objectively sustainable) can be decomposed as below.
Obj 2.1 : *be an element of natural ecosystems*
Obj 2.2 : *be an element of the traffic system*
Obj 2.3 : *be an element of the landscape*

Objective 3 (Bridge should be Subjectively sustainable) can be decomposed as below.
Obj 3.1 : *be aesthetic*
Obj 3.2 : *be enforceable of rich human experiences of nature and its phenomena*

Objective 4 (Bridge should be Inter-Subjectively sustainable) can be decomposed as below.
Obj 4.1 : *be in accordance with environmental ethics / justice (Green design ethics)*
Obj 4.2 : *be in accordance with green building cultures*
Obj 4.3: *be in accordance with the narratives of the context (cultural, historical, ethnic, religious, etc).*

Level 3 Objectives
Level 3 objectives are determined by decomposing Level 2 objectives. For example,

Objective 1.1, which is related to sustainable materials can be decomposed as below.
Obj 1.1.1 : *be constructible using renewable, recyclable and reusable material*
Obj 1.1.2 : *be constructible using alternative/ complementary material*
Obj 1.1.4 : *be constructible using low embodied energy-materials*

Objective 1.2, which is related to sustainable structural systems can be decomposed as below.
Obj.1.2.1 : *be a dismantled and re-assembled type structural system*
Obj 1.2.2 : *be an adoptable Structural System*
Obj 1.2.3 : *be an expandable Structural Systems*

Similarly all the level 2 objectives are decomposed to determine other level 3 objectives. By decomposing level 3 objectives, level 4 objectives are determined; and this process is continued up to the depth required or till the objectives cannot be decomposed further. By linking the related objectives, the objective tree can be constructed as in Fig. 5. Then the weights are assigned to all objectives considering their relative importance, as described in section 3.

Evaluating the scores of objectives
By adopting the method described in section 3, the scores of all the objectives are computed. The objectives ***Obj 1, Obj2, Obj 3 & Obj 4*** are related to the four quadrants of the AQAL modal. Hence the scores of those design objectives indicate how well each of those objectives could be achieved by the design solution considered. For example if the score of ***Obj 1*** is 50 (50 out of 100); it means the ***Obj 1*** (i.e -technological sustainability) could be achieved 50% from that design solution. If the score of ***Obj 4*** is 10 (10 out of 100), it means cultural sustainability could be achieved only by 10% by

that solution. The score of the main objective or the ***Obj 0*** indicates the degree of integral sustainability of the design solution considered.

5.0 Conclusion

The proposed framework for design of sustainable structures was based on the concept of 'Integral Sustainability'. Integral sustainability represents not only technological sustainability but also experiential sustainability, cultural sustainability, and systems sustainability. Accordingly the proposed frame work covers all the above mentioned aspects of sustainability. Non-integral approaches concentrates on one aspect of sustainability, ignoring other aspects. Accordingly mere-technological approaches ignore many other aspects of sustainability. Echo-tech approaches consider technological and ecological aspects of sustainability, but ignore cultural aspects of sustainability.

The proposed framework can be employed during the conceptual design stage for brain storming. In addition it can also used in evaluating alternative design solutions, and for selecting the best alternative. The outline of the conceptual framework presented in this paper has to be expanded to develop a comprehensive framework for a given structure. In developing the framework, specialties associated with the particular structure, physical environment, available technologies, available materials, constraints, design and construction regulations, social requirements, etc., have to be considered.

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