

# DIAGRAMMATIC REPRESENTATIONS OF SUSTAINABILITY – A REVIEW AND SYNTHESIS

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Models, and in particular diagrams, are frequently used to facilitate the understanding of complex concepts, such as sustainability. Determining the appropriateness of such representations is important if the associated notions are to be understood and related activities to be practically implemented in applicable fields, including the construction industry. An extensive review of existing pictorial models of sustainability was conducted in order to determine their propriety in relation to the sustainability concept. In addition to encompassing the conventional Venn diagram and nested circles depictions, this effort included an inspection of advanced sustainability models. It was determined that none of these diagrammatic representations adequately consider all of the key constituent elements of sustainability, namely: its notional dimensions of environment, society and economy; space and time; and the need for active participation in its implementation. Therefore a synthetic, multi-part visual model was developed to address this perceived deficiency which, when compared with contemporary construction practice, revealed the need for a holistic framework to enable a wider appreciation of sustainability's core principles as applied to the built environment.

Keywords: diagrams, modelling, sustainability.

## INTRODUCTION

The idea of sustainability has been disparaged for being “an empty concept, lacking substance” (Fortune and Hughes 1997). Similarly, the related (and frequently synonymous) notion of sustainable development (WCED 1987), has been branded nebulous, riven with contention (Taylor 2002) and intrinsically ambiguous (Wackernagel and Rees 1996: 33). Despite these criticisms, ‘sustainability’ has been institutionalised by many different interests and organisations (Giddings, Hopwood and O’Brien 2002), ostensibly as a result of political expediency (Middleton, O’Keefe and Mayo 1993) rather than exhaustive formulation. Therefore, there is a distinct risk that a sustainable future will not be realised unless the concept is expressed in a manner which allows its notional essence to be clearly exposed. As sustainable construction is the construction industry’s response to sustainable development (Ding 2005), the outcome of such a consideration has the potential to have a direct bearing

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on construction practice. It is averred here that an appropriate model of sustainability will prove to be an important step towards achieving this goal.

Waas *et al.* (2011) state that models are “simplifications of the complex reality” acquired through various modes of learning with the aim of enabling decision making. Moreover, they are “analogous to maps ... they have many possible purposes and uses, and no one map or model is right for the entire range of uses” (Constanza *et al.* 1993: 547). Multiple models of sustainability have been proposed and categorised (Todorov and Marinova, 2009), which include quantitative, standardising and pictorial models. In particular, well-constructed diagrams, especially when accompanied by sufficiently detailed explanatory text, can allow for comparatively complex ideas to be readily grasped and understood (Lozano 2006). Images are often recalled more easily than non-image data and can reveal a conceptual tangibility that may be difficult to express concisely in words. However, Giddings, Hopwood and O’Brien (2002) caution against excessive abstraction in figurative form as this may lead to a distortion of the associated theory. It is diagrammatic representations of sustainability that will be explored in this paper. A synthetic model of sustainability is proposed and the implications of this model for the construction industry are briefly discussed.

## THE VENN DIAGRAM MODEL OF SUSTAINABILITY

### Overview

Sustainability is frequently conceptualised as consisting of three distinct dimensions – environment, society and economy. The relationship between these aspects can be shown graphically by a Venn diagram (Figure 1a) composed of three overlapping circles, with each circle representing a separate dimension (O’Riordan 1998). The size of each circle and the extent by which it impinges upon the other two can be varied to express the perceived importance of each aspect relative to the others and the extent by which the dimensions are interrelated through sharing constituent elements. Most commonly, the circles are arranged symmetrically around a central area of confluence (i.e. where all three circles incompletely coincide) denoting the integration of part of each dimension such that sustainability is nominally achieved. Partial integration of the aspects is shown where only two of the three circles overlap.

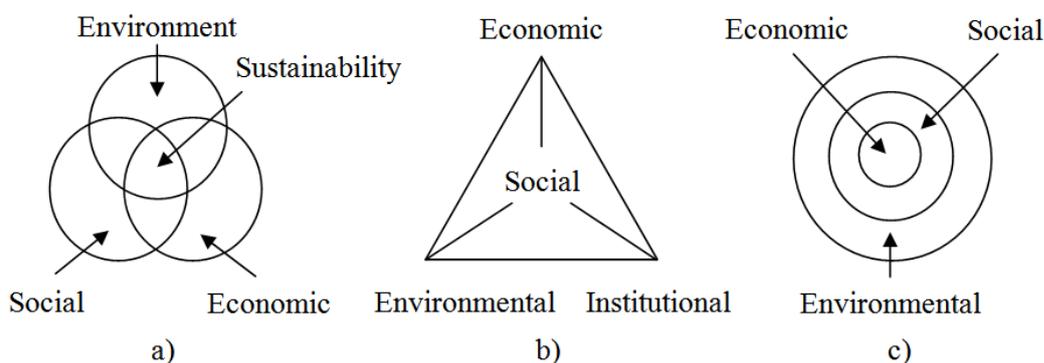


Figure 1 – Various diagrammatic representations of sustainability

### Limitations of the Venn diagram model

This model has proved to be a very popular and palatable way of relating the conceptual complexity of sustainability to a wide audience and evidence exists of the Venn diagram representation being adapted to suit the requirements of specific interests, e.g. industry recasts the dimensions as people, planet and profit (Elkington

1998). However, its simplicity is beguiling and Giddings, Hopwood and O'Brien (2002) point to three specific issues associated with this visualisation.

Firstly, they state that, fundamentally, the diagram can be interpreted as ignoring the intrinsic, immutable relationships existing between each of the dimensions. Also, it can facilitate the assumption, per the precepts of 'weak sustainability', that the unfettered substitution of physical and human capital for natural capital can occur indefinitely (Neumayer 1999). This is at odds with the 'material reality'. Similarly, Mebratu (1998) refers to the Venn diagram as a "cosmic (mis)perception". He states that by characterising the dimensions as independent systems the model falls into a reductionist epistemological trap which fails to account for the inherent interactions between "the parts, the whole and, most importantly, the interaction[s] between the parts and the whole". Moreover, areas of bivalence, where only two of the dimensions overlap, are deemed to be essentially contradictory, while, according to Lozano (2006), regions featuring no overlap can be incorrectly perceived as being unrelated to sustainability. Most pertinently, the complete visualisation does not demonstrate or sufficiently imply the logical conclusion of the concept – the full integration of the environmental, social and economic dimensions.

Secondly, despite the socio-economic focus of international efforts led by the United Nations (and the frequent portrayal of all three circles as being of the same size), there is a tendency among some proponents of sustainability to prioritise the environmental dimension above the other aspects. This can perhaps be ascribed to the comparative ease by which some measures of environmental performance can be quantified. Such an approach is counterintuitive within the context of government and business – the 'political reality' – where neo-liberal economic perspectives predominate.

Finally, it is asserted that the compartmentalisation of sustainability (i.e. addressing issues associated with each aspect in isolation), although an understandable approach based on historical precedent and the need for specialisation to enable the study of complex phenomena, encourages the employment of technical fixes to both the environment (e.g. pollution control) and the economy (e.g. landfill taxes, cost benefit analysis). Such a sectoral approach, which perceives balancing or trade-offs as appropriate actions within the solution space, frequently fails to consider wider social issues and is often implemented at the expense of a deeper understanding of the interrelatedness of the dimensions (Lozano 2006).

Notwithstanding the preceding analysis, perhaps the sharpest criticism that can be levelled at this model is that it inadequately represents issues relating to scale and the dynamic processes of change over time (Lozano, 2006).

## **SOME OTHER MODELS OF SUSTAINABILITY**

Additional models and diagrammatic depictions of sustainability have been proffered. Some are explicitly grounded in the existing Venn diagram representation (Lozano, 2008: 1842-1843). Elsewhere, other dimensions have been added to or replace the established sustainability aspects of environment, society and economy. For example, the inclusion of a 'cultural' dimension has been mooted (UCLG 2009: 17), although society and culture could be merged into a single socio-cultural aspect as these dimensions are inherently linked (BFPPS 2009). In contrast, Kohler (1999) opts to nominally replace the 'society' aspect with a 'cultural' dimension.

Reflecting the importance of institutional change in meeting the goals of sustainable development, as identified previously in *Our Common Future* (WCED 1987) and by

the UN (UN, 1992), some authors (Meadowcroft 2000, Spangenberg, 2003) have added a fourth 'institutional' aspect to the existing established dimensions (Figure 1b). This aspect is also referred to as 'democracy' or 'governance' (Waas *et al.* 2011). In this context, the institutional dimension seeks to reconcile the environment and economics in decision making so as to better express the common interest through public participation in democratic and political processes across a range of spatial scales (Spangenberg, 2004, Centre for Sustainable Development 2006: 30).

## **THE NESTED CIRCLES MODEL OF SUSTAINABILITY**

### **Overview**

Often, a different representational tact to those outlined previously is taken. Giddings, Hopwood and O'Brien (2002) maintain that the evolutionary development of mankind is intrinsically linked to society and that almost all human activities are dependent on and impact upon the natural environment. Furthermore, the economy can be identified as a subset of society; the production and exchange of goods and developments in industry, business and technology are all in part based on social interactions. Therefore, in contrast to the Venn diagram with its suggestion of equivalency between the dimensions, they commend a hierarchical model consisting of three nested circles with rotational symmetry (Figure 1c). This representation is considered to be a more appropriate depiction of sustainability as it facilitates "a conceptual outlook more sympathetic to integration" (Giddings, Hopwood & O'Brien, 2002). In this model, economy is a subset of society rather than the paramount aspect (despite its central position within the diagram) and both of these dimensions are bounded by and implicitly depend upon the natural environment. Note, however, that the environment can still exist if society is no longer present (Lovelock 1988) and, at least in some locations and on some scales, society can persist without an extant economy.

### **Limitations of the nested circles model**

However, even this improved nested circles model still has its constraints. Giddings, Hopwood and O'Brien (2002) consider the graphical representation of three unified dimensions as a further abstraction which ignores the multitude of environments, societies and economies that exist spatially (from the macro to the micro scale) and temporally. This is a valid point as such diversity is uninimical to the continued existence of humanity (Jacobs 1961). Moreover, conceiving the economy as a single entity continues to insufficiently recognise non-monetary provisioning (Langley and Mellor 2002), further embeds the misconception of the primacy of the market in meeting human needs (Lozano 2006) and fails to differentiate between beneficial and detrimental impacts of economic activity. Also, there remains an outstanding need to better represent that human enterprise and well-being (both material and cultural) are intrinsically (and unidirectionally, i.e. the dependence ultimately resides with society only) linked to the environment and can only exist within its bounds. Lozano (2006) maintains that the emphatic delimitation of the three dimensions still panders to compartmentalisation and continues to inadequately represent the relationships that endure between the dimensions. Moreover, crucial spatial and temporal considerations remain insufficiently characterised while the similarly important governance aspect is noticeable only by its absence.

## ADVANCED MODELS OF SUSTAINABILITY

### Geometric three-dimensional model of sustainability

In response to these omissions, two further, more advanced representations of sustainability are worthy of description. Lozano (2006) proposes a novel visualisation of sustainability which develops models expressed in two geometric dimensions (as differentiated from the three notional sustainability dimensions or aspects of environment, society and economy) into a single, spatially and temporally cognisant diagram composed of three geometric dimensions. This enhanced representation is essentially realised through a two-stage evolutionary process.

The first stage, which can use either the Venn diagram or the nested circles model as a developmental departure point, involves the progressive equalisation and integration of the three sustainability aspects, such that any perceptions of economic primacy (or indeed the predominance of either of the other aspects) are diminished in favour of a more integrational perspective. This action yields the First Tier Sustainability Equilibrium (FTSE), a representation of full spatial integration shown diagrammatically as a continuously rotating circle where all parts of each aspect are in concurrent dynamic contact (Figure 2a).

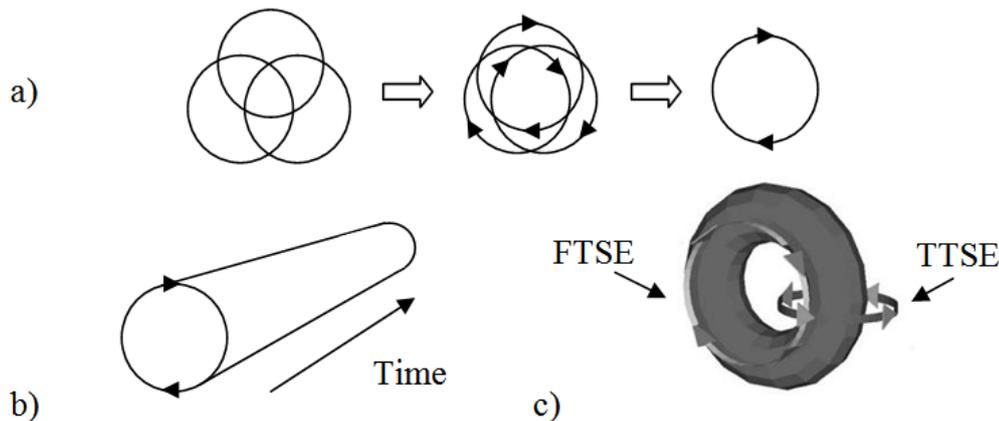


Figure 2: Diagrammatic representations of FTSE and TTSE (adapted from Lozano, 2008)

The second stage initially requires that the FTSE model is further evolved to address inter-generational concerns. Ideally, this is shown in three geometric dimensions as a perfect cylinder (Figure 2b), where there are no deviations in the interactions between and emphasis on the aspects over time such that a temporal equilibrium is established. Thereafter, the two equilibria (i.e. spatial and temporal) can be combined by “inter-relating the FTSE in dynamic change processes through time, passing from the inter-generational to the holistic perspective” (Lozano 2006) to realise the Two Tiered Sustainability Equilibrium (TTSE). This state is shown as a geometric torus (Figure 2c), where “sustainability issues lie inside the [torus] and are in perennial movement inter-relating with other issues, continuously rotating in ... two axes” (Lozano 2006).

### Five-dimensional model of sustainability

A further visualisation, provided by Seghezzeo (2009), stems from an assertion that the WCED (1987) definition of sustainable development is severely limited. Specifically, it is essentially anthropocentric, overstates the significance of the economy, largely neglects spatial and temporal considerations and fails to account for non-physiological needs such as love, safety and esteem. In response to this he proposes that sustainability is conceptually reframed so as to better account for the territorial,

temporal and personal aspects of development, as illustrated by a novel five-dimensional sustainability triangle (Figure 3). This representation displays the three conventional geometric dimensions of space (entitled 'Place'), the temporal dimension (labelled 'Permanence') and a human introspective dimension (termed 'Persons'). These aspects are shown within the triangle – the vertices of which are labelled intra-generational equity, inter-generational equity and identity / happiness – over which are laid the circles of a traditional symmetrically arranged Venn diagram. Seghezzeo (2009) notes that Place and Persons are tangible aspects that exist in the present time whereas Permanence is the idealised and subjective projection over time of events associated with Place and Persons.

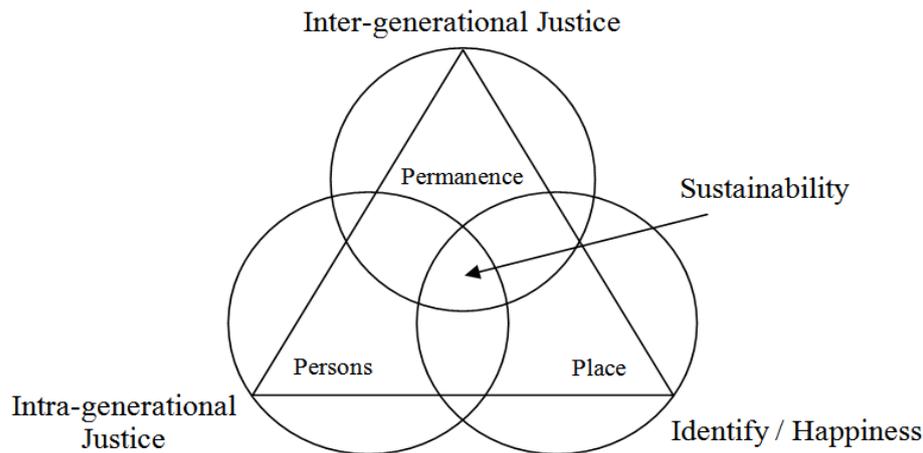


Figure 3 – Five dimensional model of sustainability (adapted from Seghezzeo, 2009)

### Limitations of the advanced models

The issues associated with the Venn diagram and nested circles models are only partially addressed by these advanced representations of sustainability. The final stage of Lozano's geometric three-dimensional model derivation presents interactions between the three notional sustainability dimensions over space and time but fails to acknowledge a need for appropriate governance. In addition, without an understanding of the detailed derivation of its form this model is somewhat transcendental. Seghezzeo's five-dimensional model similarly captures spatial and temporary considerations, relates them to human equity requirements and furthermore acknowledges the importance of the individual (and, by extension, communities and groups). However, it incorporates the substantially criticised Venn diagram into its form and, again, does not explicitly emphasise the need for procedural fairness. Despite these criticisms, these models are not without merit. They develop our understanding of the issues requiring attention, albeit not in a consummately representative manner, if a sustainable future is so to be realised.

### A CONFLATED MODEL OF SUSTAINABILITY

The previous analysis of the diagrammatic models suggests that sustainability can be conceptualised as consisting of multifarious, spatial and temporal interactions between the notional dimensions of environment, society and economy, shaped and influenced by full public participation in associated decision-making. As none of the reviewed models sufficiently address these attributes in concert, a conflated diagrammatic representation of sustainability is proposed, that acts as a synthesis of existing ideas rather than yet another exclusive visualisation. This model, which is substantially

based on the thinking of Lozano (2006), differs from previous efforts in that it seeks to make the transition to the geometric three-dimensional torus model (deemed here to be the most appropriate end point for a representation of sustainability) explicit in a single rendering (Figure 4). Thus, as a progressive triptych, the diagram reduces the requirement for extensive, accompanying descriptive text. Furthermore, it illustrates that stakeholder influence is inextricable from any consideration of sustainability.

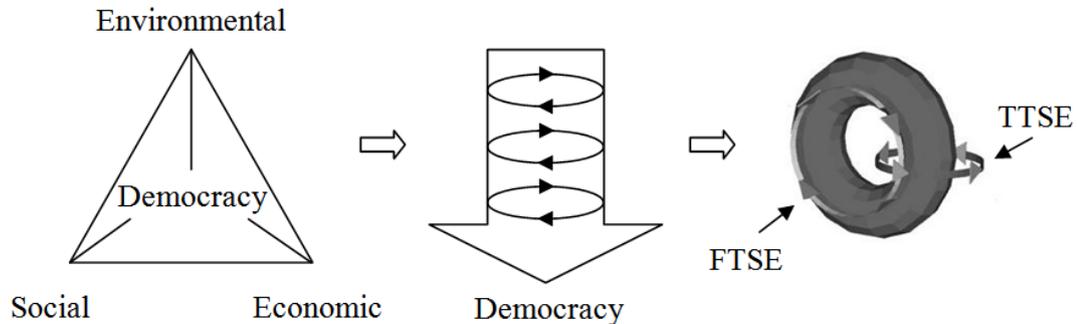


Figure 4 – Conflated model of sustainability

Following on from Meadowcroft (2000) and Spangenberg (2003), the conflated model commences with a simple ‘four pillar’ representation of sustainability, depicting the notional dimensions of environment, society and economy and the idea of full stakeholder engagement. Thought was given to the most appropriate manner by which to denote the participatory aspect. The terms ‘institutional’ and ‘governance’ imply a barrier to participation such that only Establishment interests can effectively contribute to sustainability discourse. Moreover, these expressions fail to indicate that the perspectives of individuals have the potential to bear on related activities. Therefore, it is put forward that ‘democracy’ is a more appropriate term to use in this context. Democratic participation, in its broadest application, not only represents the ability to actively contribute towards the realisation of a sustainable society but also, on a personal level, serves to empower individuals to rely on their own intimate faculties and “localised and embedded identities” when assessing the substance and weight of environmental problems (Macnaghten and Urry 1998).

Therefore, the first part of the model takes the form of an equilateral triangle with a sustainability aspect at each of its vertices and ‘democracy’ at its centre, with each line shown denoting a relationship existing between the pillars. The position of the democracy pillar is not arbitrary – its location seeks to emphasise that participation is paramount to all considerations of sustainability. The second stage of the model borrows from Lozano’s interim, spatial representation of sustainability and is shown three-dimensionally as three equalised and integrated circles in continuous rotation. However, environment, society and economy are depicted here as a three-dimensional ‘pancake stack’, physically separated but implicitly connected, and fully permeated by the notion of participation as democracy. The final part of the diagram shows the TTSE torus shape, visually identical to Lozano’s rendition but, by progressing through the previous two stages of the model, the spatial and temporal application of democracy is implied. The intervening FTSE stage is excluded from this representation as, in the opinion of the authors, it is sufficient to describe in text the spatial-to-spatial and temporal transition between the second and third parts of the model (an intuitive leap?), thus avoiding unnecessary diagrammatic complexity.

## IMPLICATIONS FOR THE CONSTRUCTION SECTOR

Having determined the notional elements of sustainability from the analysis and following an adaptation of existing diagrammatic representations of the concept, it falls to understand what insights this knowledge provides that are relevant to the contemporary construction industry. Much of the effort to implement sustainable construction focuses on the pre-hoc use of methods to assess the sustainability of buildings and other constructed assets. This is in part due to the ability of such schemes to translate the conceptual complexity of sustainability into a manageable, finite set of performance criteria (Cole 2005). However, these methods fail to sufficiently address the social and financial aspects of sustainable construction (Todd *et al.* 2001), are typically limited spatially in their application to the boundaries of assessed sites (Ding, 2008), and are found wanting in terms of life-cycle material, energy and cost considerations (Rees 1999, Cole 2005). This position risks the institutionalisation of a limited definition of sustainable construction that is not cognisant of the aspects expressed in the conflated model and therefore not fully aligned to the notion of sustainability.

Outwith the context of assessment, many sustainability challenges exist in an industry typically characterised by *inter alia* organisational complexity, contractual wrangling, and an overriding focus on short-term profit maximisation (Green 2011). This situation is further complicated by a range of distinct perspectives on sustainability (Mebratu 1998, Hopwood, Mellor and O'Brien 2005) that seek to influence the political and cultural context within which construction takes place. It is thus evident that progress towards a sustainable future through construction theory and practice will require new structures of knowledge and thinking based on an inclusive vocabulary which enables participation over the complete project lifecycle.

Such an exigency can perhaps be fulfilled by the Cosmomic Idea of Reality. Originally proposed by the Christian philosopher Herman Dooyeweerd (1894-1975) and later secularised and adapted to suit the built environment by Brandon and Lombardi (2011), this theory presents a holistic, integrated perspective on the universe through the expression of fifteen interrelated dimensions of reality, or modalities. These modalities, which include the sustainability aspects exposed in this paper as well as both lower order (e.g. numerical, kinematic) and higher order (e.g. aesthetic, ethical) dimensions, are structured in a non-arbitrary order whereby earlier modalities in the 'cosmomic order of time' serve as foundations for the later. This framework has been commended for embracing complexity while avoiding reductionism and/or subjectivity (Brandon and Lombardi 2011).

## CONCLUSIONS

Through a review of current diagrammatic models of sustainability, this paper set out to arrive at an appropriate visualisation which exposes the essence of the sustainability idea. Therefore, a synthetic model has been proposed that seeks to fully represent the identified aspects of sustainability (i.e. environment, society, economy, space, time and democracy) in a progression of figurative forms. Expressed thus, contemporary sustainability practices in construction are comparatively insufficient, in particular with regard to enduring, active stakeholder participation. This has in turn revealed the need to seek out and evaluate new structures to practically yet comprehensively address the holistic requirements of sustainability within a construction context. In response, the Cosmomic Idea of Reality, adapted to suit the characteristics of built environment, has been tentatively put forward as a suitable candidate framework.

However, it remains to be seen whether advanced diagrammatic representations, and indeed consequential frameworks, relating to sustainability can effectively capture the collective imagination of construction researchers and practitioners. Progressive pictorial models of sustainability are only recent appreciations and thus their general and built environment specific impact cannot yet be determined. Furthermore, many extant theoretical structures that attempt to capture the practical requirements of sustainability have ostensibly failed to gain widespread appeal in the manner that the adaption of Dooyeweerd's theory now seeks to achieve. This is despite an acknowledgement by some of these frameworks of the importance of time and space, e.g. BEQUEST (Bentivegna *et al.* 2002), and participation, e.g. LUDA (LUDA n.d.).

But perhaps such a denouement lacks empathy. The rigorous comprehension of sustainability, subject as it is to temporally sensitive cultural perceptions, is a relatively nascent phenomenon and there is still much to learn. Therefore, it is hoped that the conflated model presented here will prove to be an important step towards a clearer notional understanding of sustainability and thus facilitate the achievement of a sustainable future.

## REFERENCES

- Belgian Federal Public Planning Service (BFPPS) (2009) "TOPOZYM – final report" [online]. Available from: <http://www.topozym.be/spip/IMG/pdf/Topozym-final-report.pdf> (Accessed 23rd April 2012).
- Bentivegna V, Curwell S, Deakin M, Lombardi P, Mitchell G & Nijkamp P (2002) A vision and methodology for integrated sustainable urban development: BEQUEST. "Building Research & Information", **30**(2), 83-94.
- Brandon, S and Lombardi, P (2011) "Evaluating Sustainable Development in the Built Environment". 2ed. Oxford: Blackwell.
- Centre for Sustainable Development (2006) "Sustainable Development: A Review of international Literature". Edinburgh: Scottish Executive Social Research.
- Cole, R (2005) Building environmental assessment methods: redefining intentions and roles. "Building Research and Information", **33**(5), 455-46.
- Costanza, R, Wainger, L, Folke, C and Mäler, K-G (1993) Modelling complex ecological economic systems. "BioScience", **43**(8), 545-555.
- Ding, G (2005) Developing a multi-criteria approach for the measurement of sustainable performance. "Building Research and Information", **31**(1), 3-16.
- Ding, G (2008) Sustainable construction – The role of environmental assessment tools. "Journal of Environmental Management", **86**(3), 451-464.
- Elkington, J (1998) "Cannibals with forks: The triple bottom line of 21st century business". Oxford: Capstone.
- Fortune, J and Hughes, J (1997) 'Modern academic myths'. In Stowell, F, Ison, R, Armson, R, Holloway, J, Jackson, S and McRobb, S. (eds.) "Systems for Sustainability: People, Organizations and Environment". London: Springer.
- Giddings, B, Hopwood, B and O'Brien, G (2002) Environment, economy and society: fitting them together into sustainable development. "Sustainable Development", **10**(4), 187-196.
- Green, S (2011) "Making sense of construction improvement". Oxford: Wiley-Blackwell.
- Hopwood, B, Mellor, M and O'Brien, G (2005) Sustainable Development: Mapping Different Approaches. "Sustainable Development", **13**(1), 38-52.

- Jacobs, J (1961) "The Death and Life of Great American Cities". New York, NY: Random House.
- Kohler, N (1999) The relevance of Green Building Challenge: an observer's perspective. "Building Research and Information", **27**(4/5), 309–320.
- Langley, P and Mellor, M (2002) 'Economy', sustainability and sites of transformative space. "New Political Economy", **7**(1), 49–66.
- Large Urban Distressed Areas (LUDA) (n.d.) "LUDA Project" [online]. Available from: <http://www.luda-project.net> (Accessed 28th May 2012).
- Lovelock, J (1998) "The Ages of Gaia: a Biography of our Living Earth". Oxford: Oxford University Press.
- Lozano, R (2008) Envisioning sustainability three-dimensionally. "Journal of Cleaner Production", **16**(17), 1838-1846.
- Macnaghten, P and Urry, J (1998) "Contested natures". London: Sage Publications in association with Theory, Culture and Society.
- Meadowcroft, J (2000) Sustainable development: A new(ish) idea for a new century? "Political Studies", **48**(2), 370-387.
- Mebratu, D (1998) Sustainability and Sustainable Development: Historical and Conceptual Review. "Environment Impact Assessment Review", **18**(6), 493-520.
- Middleton, N, O'Keefe, P and Mayo, S (1993) "Tears of the Crocodile: From Rio to Reality in the Developing World". London: Pluto Press.
- Neumayer, E (1999) "Weak Versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms". Cheltenham: Edward Elgar Publishing.
- O'Riordan, T (1998) Indicators for Sustainable Development. In: "Proceedings of the European Commission (Environment and Climate Programme) Advanced Study Course", 5-12 July 1998, Delft, The Netherlands.
- Rees, W (1999) The built environment and the ecosphere: a global perspective. "Building Research and Information", **27**(4), 206–220.
- Seghezze, L (2009) The five dimensions of sustainability. "Environmental Politics", **18**(4), 539-566.
- Spangenberg, J (2003) "New challenges need new answers", Keynote speech to EPA Ireland 10th Anniversary Conference: Pathways to a Sustainable Future, 15 May 2003, Dublin, Ireland.
- Spangenberg, J (2004) Reconciling sustainability and growth: criteria, indicators, policies. "Sustainable Development", **12**(2), 74-86.
- Taylor, J (2002) "Sustainable Development – A Dubious Solution in Search of a Problem" [online]. Available from: <http://www.cato.org/pubs/pas/pa449.pdf> (Accessed 23rd April 2012).
- Todd, J, Crawley, D, Geissler, S and Lindsey, G (2001) Comparative assessment of environmental performance tools and the role of the Green Building Challenge. "Building Research and Information", **29**(5), 324–335.
- Todorov, V. and Marinova, D. (2009) Models of Sustainability. In: Anderssen, R, Braddock, R and Newham, L, "18th World IMACS / MODSIM Congress", 13-17 July 2009, Cairns, Australia, 1216-1222
- United Cities and Local Government (UCLG) (2009) "Culture and sustainable development: examples of institutional innovation and proposal of a new cultural policy profile". UCLG.

- United Nations (UN) (1992) “Agenda 21: The United Nations programme of action from Rio” [online]. Available from: <http://www.un.org/esa/dsd/agenda21> (Accessed 23rd April 2012).
- Waas, T, Hugé, J, Verbruggen, A and Wright, T (2011) Sustainable Development: A Bird’s Eye View. “Sustainability”, **3**(10),1637-1661.
- Wackernagel, M and Rees, W (1996) “Our Ecological Footprint: Reducing Human Impact on the Earth”. Gabriola Island, Canada: New Society Publishers.
- World Commission on Environment and Development (WCED) (1987) “Our Common Future (The Brundtland Report)”. Oxford: Oxford University Press.