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Towards a regenerative paradigm for the built environment

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Abstract
The concept of regenerative design and development is situated within the broader theoretical context of sustainability. The emerging regenerative paradigm is contrasted with the two current sustainability paradigms – internationally negotiated 'idealistic' public policy and private sector 'Ecological Modernization' – that seek to maintain the status quo. Each of these sustainability paradigms is explained though a brief historical narrative to illustrate their response to broader social pressures, the main critiques of each and some commonalities. It is argued that the dominant sustainability paradigms are reaching the limitations of their usefulness due to their conceptual foundation in an inappropriate mechanistic worldview and their tacit support of a modernization project that prevents effective engagement with a complex, dynamic and living world. The regenerative paradigm provides an alternative that is explicitly designed to engage with a living world through its emphasis on a co-creative partnership with nature based on strategies of adaptation, resilience and regeneration. It provides a foundation for a sustainability paradigm that is relevant to an ecological worldview.

Keywords: built environment, ecologism, regenerative design, resilience, sustainable building, sustainable design, urban sustainability

Introduction
The concept of regenerative design and development needs to be considered within the broader theoretical context of sustainability. The intention is not to provide a detailed account of the many different theories, schools and movements that constitute the environmental and sustainable development discourse [1]. The objective is rather to juxtapose the emerging 'regenerative' paradigm [2] that is the subject of this special issue and the two dominant paradigms in the current sustainability discourse through historical narrative of their development from social, cultural and worldview perspectives.

Each of these sustainability paradigms arose in response to new pressures in both the natural and socio-cultural environments with new actors coming into play. Kidd (1992, p. 2) describes how the concept of sustainability grew from a set of diverse, yet equally valid and often interlinked streams of thought. These streams of thought were themselves the products of larger societal concerns that came to shape the agendas of governments, business and civil society after the Second World War.

The conflict between development and protecting the regenerative capacity of the natural environment is not new. Admonishments to take only what is needed from nature can be found as far back as the Upanishads (Prime, 2002, p. 132), while the origins of sustainable resource use have been traced back to medieval German forestry practices (Held, 2000).

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However, during the 20th century the scale of human needs and the impact of meeting those needs on the ability of ecological systems ('nature') to continue meeting them reached critical dimensions.

The initial responses to this crisis laid the foundations for the different sustainability paradigms that are discussed in this paper. The first of the paradigms under consideration evolved in public policy. It was driven by the United Nations (UN) and aimed to develop a set of common criteria, indicators and strategies through international consensus.

The second paradigm evolved in the private sector as businesses responded to the risks, pressures and opportunities presented by an environmental agenda. Both these paradigms have been criticized for their perpetuation of the structures of society that created the crisis in the first place. According to the critics these structures are not just the systems of production or the organization of the economy, but include the very worldview that underlies modern society. The modern world, it is suggested, was built on an expansionist worldview rooted in a mechanistic metaphor (Capra, 1997; Rees, 1999). This worldview holds that nature can be seen as a machine that can be understood and managed by reducing it to its parts. Humans are seen as separate and above nature (Rees, 1999, p. 24) and able, through technology and science, to control nature to address the problems imposed on human society by the 'external limits' of nature (Redclift and Sage, 1994, p. 17).

The third paradigm to be discussed evolved from what has been described as radical 'ecologism' (Dobson, 1990, p. 13; Mol and Spaargaren, 2000, p. 31) that calls for profound and radical changes to the structures of society, including the dominant worldview, in order for the Earth to remain fit for human habitation. This paradigm underlies regenerative design and development. Unlike the development of the other two paradigms, what eventually became the regenerative sustainability paradigm evolved in parallel from the grassroots efforts of people from all walks of life. Underpinning the development of ecologism are two questions: How can we learn to live in harmony with nature?; and How can our efforts make the world a healthy and life-enhancing place? The process of addressing these questions became what Rees (1999, pp. 42–43) called: the first intentional paradigm [worldview] shift in the history of our species.

Laying the foundations of sustainable development

Shortly after US President Harry Truman announced the Age of Development in his 1949 inaugural speech, the nascent environmental movement that emanated from pre-war conservationist organizations such as the Audubon Society and the Sierra Club in the US raised the first concern. This is the need to reconcile the protection and conservation of 'the environment' with the demands of industrial development and economic growth. This led to a number of international conferences organized under the auspices of the UN (e.g. the United Nations Scientific Conference on the Conservation and Utilization of Resources in Lake Success, 1949; and the United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere in Paris, 1968). The need to construct a rationale for the conservation and protection of natural resources, wilderness areas and endangered species as a counterpoint to the rapacious practices of industrialization laid the foundation for later utilitarian concepts such as ecological economics and ecosystem services found in ideas that underpins the Ecological Modernization movement.

The second concern came from what would later be called the Brown Agenda (McGranahan and Satterthwaite, 2000). This is focused on the problems of providing a safe, healthy and equitable habitat for the rapidly growing global human population. Although colonies gained political independence in the aftermath of the Second World War, their aspirations for a society based on material affluence were further shaped by Cold War politics and this created substantial developmental lock-in. Several societies labelled as underdeveloped by the UN embraced the agenda of modernization, that is:

> the transformation of traditional societies into modern ones characterized by advanced technology, material prosperity and political stability. (Hobart, 1993, p. 5)

This modernization project was expressed in the built environment through embracing the principles of the Modern Movement and automobile-based town planning schemes. In some countries (notably Brazil, Mexico and South Africa) architects attempted to develop regional hybrids that were climatic and culturally responsive, but most of the world uncritically replicated inappropriate interpretations of Modernist architectural ideals to accommodate the needs of rapid urbanization. The result was an urban form and building stock that was socially dysfunctional, highly resource inefficient and unhealthy (Jacobs, 1961/1992; World Health Organisation (WHO), 1999).

At the same time, an exploding world population meant that a large percentage of the global population continued to live without the basics of clean water, energy, adequate sanitation and tolerable shelter. Meetings such as the United Nations World Food Conference (Rome, 1974), the UN-Habitat Conference (Vancouver, 1976) and the UN Water Conference (Mar del Planta, 1977) placed the spotlight on the plight of the poor in the so-called 'developing countries' by calling for a range of development measures. These had still not been achieved by the time the Millennium Developmental Goals were formulated two and a half decades and several billion dollars of development aid later. The impetus provided by these early UN conferences led to the paradigm of negotiated sustainability expressed in documents such as the Agenda 21 and the Habitat Agenda.

It was not long before concerns were raised that the Brown Agenda, and indeed the whole development project may, in the words of the Cocoyoc Declaration, place 'the "outer limits" of the planet's physical integrity at risk' (United Nations Environment Programme/ United Nations Commission on Environment and Development (UNEP/UNCTAD), 1974, p. 1). Seminal publications such as Silent Spring (Carson, 1962), Blueprint for Survival (Goldsmith et al., 1972), and The Limits to Growth (Meadows et al., 1972) offered both scientific and ethical critiques of 'the industrial way of life' (Goldsmith et al., 1972, p. 21) and the feasibility of unfettered growth. The result was a growing understanding of the systemic and interdependent nature of the world and the need for a more harmonious and cooperative relationship between humans and nature.

This insight, combined with the memory of the depredations of the Great Depression and the Second World War, along with the uncertainty of the Cold War led to a deep distrust in the ability of central governments to provide personal and material security. The anti-establishment sentiments of the 1960s, and the energy crisis of the 1970s, saw the development of a strong self-sufficiency movement based on locally available, renewable resources and appropriate, small-scale technology as a conscious attempt to limited both consumption and development (Vale and Vale, 2010). There were significant publications such as Shelter (Kahn and Easton, 1973), Small is Beautiful (Schumacher, 1974), and The Autonomous House (Vale and Vale, 1975). In addition, initiatives such as Paolo Solari's Arcosanti, the Centre for Maximum Potential in Texas, the Centre for Regenerative Studies in California, the Centre for Alternative Technology (CAT) in Wales, and ecovillage prototypes (such as Findhorn in Scotland and Crystal Waters in Australia) provided the inspiration for ways of living that could be seen as more harmonious with nature. The practices and technologies developed by this movement formed for many years the mainstay of proposed 'green' building and living solutions: renewable energy generation; natural building materials (e.g. earth and straw bale); organic farming, permaculture and urban agriculture; and the development of alternative models of communal living such as co-housing, eco-villages and local currencies. It is from these antecedents that the regenerative paradigm evolved.

These early solutions and approaches were appropriate for small-scale rural and peri-urban contexts, but were in many ways impractical for application at an urban scale or the realities of urban growth. Due to their popularity in the counter-culture movements of the 1960s and 1970s, these approaches were marginalized by mainstream society. However, the foundations laid by this movement continue to inform green building practices, as well as sustainable development policy and activism, and encouraged the UN to proceed with a range of initiatives to establish an international political consensus on the way forward.

A negotiated sustainability

The eco-development root of sustainability led to the development of frameworks for what was to become sustainable development as interpreted by the world's governments (Kidd, 1992). This was achieved through meetings such as the 1972 UN Stockholm Conference on the Human Environment and the 1974 UNEP/ UNCTAD Symposium on Patterns of Resource Use, Environment and Development Strategies in Cocoyoc, Mexico, and publications such as Our Common Future (World Commission on Environment and Development (WCED), 1987). The 1992 Earth Summit in Rio de Janeiro presented the first international political consensus document formulated as benchmark and action plan for sustainable development, known as Agenda 21 (United Nations Commission on Environment and Development (UNCAD), 1992). Chapter 7 of Agenda 21 proposed the promotion of sustainable human settlements as integral to the achievement of sustainable development. To address further the role of human settlements in sustainable development, a second international consensus document describing the qualities and needs of sustainable human settlement development, the Habitat Agenda (United Nations Commission on Human Settlement (UNCHS), 1996), was adopted in 1996. The Agendas were later followed by the Millennium Declaration (United Nations, 2000) and associated Millennium Development Goals.

These documents aspire to an idealized society where everyone has adequate shelter, clean water, electricity, a safe and healthy social and physical environment, a dignified job, a decent education, protection from all kinds of injustice and the freedom to pursue their religious and political convictions and their lifestyle of choice, while at the same time being good to the natural environment. Numerous sets of principles, characteristics and 'dimensions' of sustainable cities have been proposed based on these UN Agendas. These are generally based on concepts such as high density living, compact cities, more sustainable transport patterns, mixed-use neighbourhoods, decent affordable housing, integrated development planning and local self-determination.

Looking backwards to Utopia?

The quest for Utopia contained in the UN documents is reflected in models proposed for sustainable cities based on nostalgic visions of the ideal, liveable and environmentally sustainable city. The consequence is 'the building of new cities which resemble old ones' (Ellin, 1999, p. 13). A prominent example is the New Urbanism of Peter Calthorpe, Andres Duany, Elizabeth Plater-Zybek and others, which draw upon European cities and small-town America for their historical references (Calthorpe, 2004, p. 75). They propose compact city models with walkable streets and clearly defined medium-density mixed neighbourhoods connected through a system of public transit nodes. Ecological design ideas proposed by, amongst others, van der Ryn and Cowan (2007), Graham (2003) and Newman and Jennings (2008) provided a set of parameters for the 'ecotopia' (Callenbach, 1975) to be delivered by the sustainable city at scales from buildings upwards.

The rapid urban development in Asia and the Middle East afforded the opportunity to design and develop entire new cities or urban districts according to these principles, in projects such as Dongtan and the Lu Zia Sui extension of Shanghai in China, Putrajaya in Malaysia, and Masdar City in Abu Dhabi. On a smaller scale, there have been a number of famed New Urbanist developments such as Seaside, Kentside and Laguna Beach in the US. In Europe, a parallel movement of 'green urbanism' (Beatley, 2004, p. 251) resulted in sustainable development districts such as the Leidsche Rijn (Utrecht), Rieselfeld (Freiburg), Ørestad (Copenhagen), Vikki (Helsinki), Bo01 (Malmo¨) and BedZED (London).

Establishing these newly created cities or neighbourhoods as vibrant and living communities fulfilling their utopian promise proved to be problematic. These projects have had mixed success, especially outside Europe. Beatley (2004, p. 251) speculates that the European projects have been more successful because they relate to familiar spatial forms and the centuries-old tradition of city living. In countries without this pre-existing compatible urban template the projects often ran into intractable obstacles of a different, and perhaps inherently incompatible, nature. The most pernicious of these obstacles were lifestyle and socio-economic patterns and assumptions around the feasibility of urban densification. In Australia, the validity of the numbers used to promote urban consolidation was questioned and the effectiveness of Smart Growth policies was criticized as being unfeasible (Troy, 1996). Wheeler (2004, p. 119) describes a number of problems experienced in the New Urbanist developments in the US, the most notable of these being that living communities take time to establish, and that modern working and shopping patterns in the US cannot be artificially shoe-horned into the small-town or European urban lifestyles promoted by the New Urbanist movement.[3] As Ellin (1999, p. 157) points out, these ideals fell into the trap of 'environmental determinism, presuming that traditional urban forms will engender traditional urban lifestyles'. Furthermore they failed to take into account 'that new transportation and communications technologies have subverted the logic of the pre-modern city with its high density and tight mix of building functions'.

The examples in Asia and the Middle East are too recent (with some still existing mainly on paper) for drawing any conclusions regarding their success. However, as Frei (1999, p. 33) suggests, there is no real evidence available to privilege one urban form over another, and empirical research suggests that the compact city model may have economic benefits, but not necessarily environmental or social benefits (e.g. Burton, 2000; van der Waals, 2000; Thinh et al., 2002; Lin and Yang, 2006).

Creating Utopia through consensus?

While the ideals described in the above-mentioned UN documents cannot be morally challenged, whether their specific interpretation of sustainability truly represents a new way of thinking about development can be questioned. At the World Summit on Sustainable Development (WSSD) in 2002 it became clear that there are two groups using the same vocabulary, but each meaning something very different. The one group (e.g. World Bank, 1992, p. 3; United Nations Development Programme (UNDP), 2003, p. 2) asks: 'How do we sustain development?' The other group (e.g. Raskin et al., 1998, p. 2) asks how we develop to sustain 'the integrity of combined human and natural systems as they interact and condition one another over time'.

The emphasis of strategies such as the UN Millennium Development Goals and the New Partnership for Africa's Development is on development and neoliberal economic growth to ensure that the 'developed' countries can maintain their current lifestyle and that developing countries are 'on a path of sustainable growth and development' (NEPAD, 2001, para. 67) that will place them on par with the developed world. The result often is delivery-wish lists based on a specific cultural interpretation of development and of what constitutes acceptable economic models (as identified by The World Bank, the International Monetary Fund (IMF) and the UN). In the process sustainable development became reinterpreted to mean 'sustained development'.

Critics of the sustained development agenda argue that the original objective of the global sustainability project (to resolve the problematic nature of the human–nature relationship) was lost in the process and, more significantly, that the development agenda on which it is based is suspect in itself. The international development project has been soundly criticized. Firstly, for the negation of non-Western, non-industrialized cultures, values and technologies as inferior, and the replacement of these with the monoculture of a particular cultural expression of progress (Esteva, 1993; Sachs, 1993). Secondly, for linking poverty to the inability to consume the products of the industrial and technological development process, thus fuelling a consumption-based interpretation of growth and development that ignored existing social and cultural systems of relationship and knowledge (Dia, 1992; Escobar, 1993; Illich, 1993; Lummis, 1993; Rahnema, 1993). And thirdly, for instituting a needs-based programme of development that moved beyond the basic necessities of life to an ever-growing range of needs, rights and entitlements as people aspire to meeting the next level of lifestyle needs (Illich, 1993).

Thus, underlying both the international political consensus on sustainable development and the principles of sustainable human settlement that flowed from it is the assumption that the social and economic problems proposed as foundational to the international sustainable development project (and their suggested remedies) are universally true. In fact, they are the product of an ideologically inspired and politically negotiated process largely dominated by the values, traditions and economic systems of the developed world.

A profitable sustainability

While governments were busy pursuing the idea of ecodevelopment, the private sector was pursuing the quest of a steady-state model of economic growth and resource consumption. This eventually coalesced into the idea of 'Ecological Modernization'. This posits that a market-based system of consumption and production is not incompatible with significant environmental reforms and does not automatically lead to more environmental devastation (Mol and Spaargaren, 2000, p. 36). The main objective of Ecological Modernization was to reconcile the needs of business and the need to protect the environment. This paradigm emerged during the 1980s and 1990s at a time when the world was being pulled out of recession by the neo-liberal free-market economic policies and their emphasis on privatization of state enterprises and services. Privatization combined with globalization meant that multinational corporations (and thus business) came to wield more power than national governments (or political ideologies) (Mathews, 1997, p. 57). Sustainability advocates soon learnt that they needed to engage with business and to do so at its own level, using business language.

The one argument that proved effective in this new era of expansionist economic growth and increased materialism was the notion of limits. While the actual predictions of The Limits to Growth (Meadows et al., 1972) were severely criticized, the key message about critical environmental limits had become accepted. This was supported by the discovery of the ozone hole, the body of research data revealing the extent and pace of environmental degradation and biodiversity loss, and the first indications of possible anthropogenic climate change. However, this resulted in the reframing of the sustainability debate as a matter of determining limits (e.g. ecological footprints, fair shares, sink and source capacities, efficiency factors) and then living within these limits – in other words, determining how much damage can feasibly be inflicted. The main impetus of the debate also now shifted away from environmentalists and social activists to be taken up by economists. This repositioned the economy from its place as an intermediary in the human–environment relationship to become a separate 'pillar' in the new sustainable development triad of people, planet and profit/prosperity. This widened the debate to embrace the interests of business and allowed for a utilitarian approach to the natural environment. As a result, an economic use value could be assigned to the natural environment and this value was calculated according to the utility of the various 'services' provided to humans by ecosystem processes.

This paradigm introduced two distinct, though related, approaches to more sustainable business practices. The first, loosely called 'sustainable capitalism', focuses on ensuring that the inheritance left to future generations is not diminished (Pearce et al., 1989). The starting premise of sustainable capitalism is the idea that the goal of sustainability would be achieved if the Earth's capital were non-declining (Dresner, 2002, p. 75). This is measured by determining the stocks of five types of capital: financial, human, social, manufactured and natural (Department for International Development (DFID), 1999; Sigma Project, 2003; Parkin, 2005). All five capitals are considered necessary to prepare the balance sheet of sustainable development, and the economy needs all five to function properly, although there is fierce debate about their substitutability (Victor, 1991; Costanza and Daly, 1992; Daly, 1997).

The second approach, 'eco-efficiency', builds on the acknowledgement of limits to resources, and aims to improve the efficient use of resources. In 1991, the World Business

Council for Sustainable Development (WBCSD) adopted the term 'eco-efficiency' to sum up the 'business end' of sustainable development (Schmidheiny, 1992). In essence, eco-efficiency is a management philosophy that encourages business to search for environmental improvements that yield parallel economic benefits. While business sees the term as standing for both economic and ecological efficiency, which aims at creating more value with less impact, the European Environment Agency defines eco-efficiency as 'more welfare from less nature' (WBCSD, 2000, p. 9). Underpinning the eco-efficiency movement is the acceptance of finite resources and limited sink capacities. If continued economic growth is to meet the ever-expanding needs of human development in an equitable manner, then more must be achieved with fewer resources.

Doing more with less is not a new concept in industry, and it was therefore an easy premise for business to understand. It also has economic benefits, as has been illustrated by the numerous examples (cf. Elkington,1998; Hawken et al., 1999; WBCSD, 2006). Tools for eco-efficiency include ideas such as Environmental Management Systems, Life Cycle Analysis (LCA) and Management, Cleaner Production, Environmental Supply Chain Management, and Design for Environment (WBCSD, 2006, pp. 25–26). In the built environment this translated into the improved energy efficiency and energy optimization strategies in green buildings, and concepts such as high-performance buildings, design for deconstruction and disassembly, and LCA of building products and materials. In general, eco-efficiency proposes a subtle shift in business practice that results in broad improvements to current industrial production models (e.g. the concepts of Factor Four and Factor Ten efficiency) without questioning too deeply the fundamentals of modernization, or requiring a broader ethical framework from its participants.

Making the economy one of the pillars of sustainability also permitted the importation of management practices from business. The terminology in this variant of sustainability reflects standard business concepts (e.g. bottom lines, capital, efficiency, risk management, performance standards), and suggested sustainability tools (e.g. resource economics, indicators, cost–benefit analysis, environmental trade-offs such as carbon trading). For the built environment this meant a shift in emphasis from design innovation to performance measurement, monitoring and evaluation. It also created the idea of green building as a competitive business advantage.

Measuring sustainability: rating and assessing shades of green

The notion of measurement as the basis of management, and therefore of the need for indicators that are 'measurable, comparable, transferable, informative and acceptable for policy choices' (Finco and Nijkamp, 2001, p. 294), led to the development of numerous urban and building sustainability indicator sets. These were often based on two sets developed by the UN: the CSD Working List of Indicators (United Nations Commission on Sustainable Development (UNCSD), 1996) and the indicators developed by UN-Habitat (2004) to measure implementation of the Habitat Agenda. The European Union 5th Framework Project Construction and City Related Sustainability Indicators (CRISP) identified 40 indicator systems used for built environment assessment, comprising a combined 510 indicators across four scales of the built environment and seven different indicator types (Bourdeau and Nibel, 2004). These include methods such as ecological footprints, environmental auditing, LCA, and complicated aggregate rating and assessment systems such as the Green Building Code, the Quantitative City Model, Eco-points, Leadership in

Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), and Green Star. The evolution of green and sustainable building rating and assessment tools is discussed in more detail by Cole (2012).

However, using indicators as a means for measuring or assessing the sustainability of cities and construction practices is being criticized for several reasons. One of the main concerns is the way in which indicators are developed through ad hoc processes without a structured framework or consensus on what built environment sustainability is (Alberti, 1996; Mitchell, 1997; Bossel, 1998; Lundqvist, 2000; Lundin and Morrisson, 2002). Secondly, and perhaps most critical, many of the indicators reflect the specific interests of their authors (Bossel, 1998, p. 73) or are contingent upon targets set by policy-makers. As Alberti (1996, p. 417) points out, 'a given agent or organization will place varying degrees of importance on the social, economic and physical dimensions of the urban environment'. Thus, the development of indicators is 'a dialectic process that goes hand in hand with the development of policies' (Foxon et al., 1999, p. 146) and not necessarily the product of an empirically derived understanding of what would constitute sustainability in the particular domain in which the indicator is to be used for assessment.

Birkeland (2005, 2007) and Schendler and Udall (2005) criticize current indicator-based building assessment and rating systems as tending to reinforce existing building types and practices. These practices try to improve on flawed 'best practice' through aggregate technical solutions or, even worse, deteriorating into mere 'accounting games' that obscures total resource flows and systemic interactions. Moreover, this approach discourages solutions that build on synergies and symbiosis (Birkeland, 2007, p. 4). These arguments are also valid for many larger-scale applications of indicator systems, as discussed by Bossel (1998), Brugmann (1999) and Meadows (1999).

Kohler (2002) raises a number of shortcomings about a formulaic approach to sustainability based on metrics and checklists. The biggest concern with this formulaic approach is that a reliance on aggregation methods for the assessment of different interventions in such a complex dynamic system does not easily lend itself to a systemic understanding of the city. Such an approach remains a mechanistic, as opposed to a systemic solution to introducing considerations of sustainability into building and urban development processes (du Plessis and Cole, 2011).

Despite the stated shortcomings of rating and assessment systems, these have created a very effective incentive for green building, and in the process a very lucrative industry. The overall global green building market (both non-residential and residential) is likely to more than double from US\$36–49 billion in 2009 to US\$96–140 billion by 2013. In addition, the environmental benefits attributable to the LEED programme include an estimated reduction of 35 million tonnes of CO_2 by 2013 (McGraw Hill Construction, 2009).

Managing sustainability by measuring flows

The concept of urban metabolism attempts to address the need for a systemic approach lacking in an indicator-based approach. Urban metabolism builds on the understanding of the city as an ecosystem with inputs of energy and materials and outputs in the form of waste products (Newman, 1999, p. 220). Girardet (1996) popularized the concept, suggesting that cities should aim for a circular metabolism that minimizes new inputs and maximizes recycling, instead of their currently linear metabolisms. This would require understanding the natural and technical metabolic flows in a city (or building) and how those flows can most effectively be directed to achieve, for example, a zero waste approach (as suggested by Bai, 2007). Kibert et al. (2002, p. 25) propose that the construction of the city itself should also be based on ecological principles, with a construction metabolism based on 'resource utilization in the built environment that mimics natural system metabolism by recycling materials resources and by employing renewable energy systems'.

However, Tansey (2006) and Alberti et al. (2003) criticize the notion of closed, localized systems with circular metabolisms that self-regulate into an equilibrium state. They suggest that as 'old' ecological thinking is not appropriate for the open, dynamic and highly unpredictable nature of complex living systems such as cities.

Several methods have been put forward for studying the metabolism of cities and their buildings, including material and energy flow accounting (e.g. Odum, 1967, 1997, 2002; Haberl et al., 2004), whole system metabolism (Wolman, 1965; Boyden et al., 1981; Girardet, 1996) and the estimation of the ecological footprint of the city (Rees and Wackernagel, 1996; Rees, 1997). These routes take existing ecological concepts and methodologies and apply them to the dynamics of resource use in cities. Moffat and Kohler (2008, p. 257) suggest that establishing the metabolic flows of a city through tools such as material flow analysis (MFA), life-cycle analysis (LCA) and the use of visual models such as Sankey diagrams, reveals the ecological efficiency of a city and critical system interdependencies. These analytical tools assist with the identification of 'the most obvious opportunities for ecological design interventions'. However, they also warn that concepts such as MFA and LCA, while convenient for modelling, remain reductionist and do not necessarily address 'the potential for a more symbiotic relationship between built and natural environments' (Moffat and Kohler, 2008, p. 261), and therefore call for a formalized structure for the various models and subsystems that can describe cities as social–ecological systems.

Flaws in the business model

There are three fundamental flaws in the business driven variant of sustainability. The first is that the language and concepts of business lead automatically to the calculations of quantitative limits and indicators, as well as monetary values of the different forms of capital. The latter opened the door to a perception of the world that sees both nature and humans as economic commodities. It is a short step to where every interaction between humans and the biophysical environment is turned into a financial transaction in which sustainable development is seen as mainly an accountancy problem to be solved by the new economic model of sustainable capitalism, as proposed by inter alia Elkington (1998). Furthermore, the notion of being able to calculate (economic) values and limits assumes the possibility of reasonably accurate predictions of such limits and that everything can be reduced to a monetary value. However, there are also qualitative and normative limits to current models of growth and development that are impossible to predict, let alone quantify or price in currency of any sort.

The second flaw is the idea that sustainability can be achieved through a piecemeal problem-solution approach, with the aggregate of solutions to separate problems somehow adding up to a sustainable building or city. This approach can be seen in the international consensus documents, as well as in the many assessment systems and indicators currently in use. However, it can be argued that (urban) sustainability is a systemic problem (Capra, 1997, 2002; Bossel, 1998; Gunderson and Holling, 2002; Alberti et al., 2003; Newman and Jennings, 2008; Moffat and Kohler, 2008) and what therefore needs to be considered are not just the individual problems and their solutions, but also the relationships and interactions between problems in a dynamic and ever-changing system. From this viewpoint, sustainability is not an aggregate of social–economic–technological solutions, but rather an emergent property arising from the interactions of all these systems.

The third problem is that those advocating that effective and efficient management will solve the problem do not fully appreciate the complexity of the systems that will have to be managed and that 'the behaviour of natural systems is fundamentally unknowable' (Rees, 1999,p. 24). As is being discovered in the science of climate change, nature is simply too complex to allow prediction of limits with any confidence. A critical flaw in the technocratic approach is the application of static thinking (e.g. criteria, checklists, targets) to dynamic processes, leading to the notion of an optimal, sustainable state, 'a preferred end-state' (Moffat and Kohler,2008, p. 263) in which rates of consumption are harmonized with constraints imposed on such consumption by natural systems, as suggested by ideas such as the ecological footprint and the Natural Step (Moffat and Kohler, 2008, p. 264).

Ecological Modernization has also been criticized for its failure to engage with some of the fundamental problems of modernization, its largely uncritical stance regarding the transformative potential of industry and modern capitalism, a perceived 'pre-occupation with efficiency over broader concerns about aggregate resource consumption', and the 'Northern Euro-centricity' that underlies its theory and exemplars taken primarily from a set of countries with developmental conditions that are 'distinctive by world standards' (Buttel, 2000, p. 64).

Eco-efficiency has failed meaningfully to address the nature of the current adversarial and eventually mutually destructive relationship between humans and their biophysical environment. However, Ecological Modernization has been instrumental in providing incentives for what Hawken et al. (1999) and McDonough and Braungart (2002) describe as the next industrial revolution and the next paradigm to be discussed.

A regenerative sustainability

While the politicians, planners, economists and businessmen were developing their versions of sustainability, the mavericks of 'radical ecologism' were opening another pathway based on a different worldview. This worldview represented a shift from seeing the planet as a deterministic clockwork system in which humans are separate from nature to seeing it as a fundamentally interconnected, complex, living and adaptive social–ecological system that is constantly in flux. In this system, humans are seen as an integral part of nature and partners in the processes of co-creation and co-evolution instead of being merely users or clients of various ecosystem services. Philosophical antecedents of this latter view can be found in indigenous knowledge systems from all the inhabited continents, Eastern philosophical and religious traditions, as well as in the ideas of Western thinkers such as Baruch Spinoza, Alfred North Whitehead, Jan Smuts and Carl Jung. It is therefore not strictly speaking a new worldview, but rather a rediscovery of an old view now bolstered through the addition of scientific discoveries in fields ranging from quantum physics to ecology.

This view changes how sustainability is understood in three fundamental ways. Firstly, it introduces the understanding that to be sustainable, it is necessary to move towards a developmental model that aligns human development efforts with the creative efforts of nature. This means following a development approach based on how nature works, not on how humans would like the world to work. Secondly, the idea of the world as an ever-changing, impermanent and inherently unpredictable set of processes is shifting the interpretation of how sustainability should be defined. Thirdly, the notion that humans and nature are not two separate interacting systems, but rather one autopoietic system where members of the species Homo sapiens participate in the production, transformation and evolution of the ecosystem in which they find themselves. This introduces the idea that humans are not only to be responsible for consequences of their actions (reducing impact), but for the general health and well-being of the whole system of which they are part. These three insights form the basis of the regenerative paradigm.

Aligning human development with the efforts of nature

McGrath (2003, p. 183) argues that 'our attitude towards the world must be grounded in the deep structures of nature – structures that we did not place there and did not invent, but that were there before us, and must shape our responses to nature'. If humans are part of nature, then they should follow the 'rules of nature'. Various such rule sets have been defined by Robert (1995) and Benyus (2002), and most succinctly by Barry Commoner as: Everything is connected to everything else; everything has to go somewhere; there is no such thing as a free lunch; and Nature knows best (Commoner, 1971, p. 41).

The design and construction of mutually beneficial and life-supporting relationships between built and natural environments, with the built environment following the 'non-negotiable laws of nature' (Graham, 2003, p. 8) and 'emulating life's genius' (Benyus, 2002, p. 2) relies on the co-evolution of several sustainability strategies on an operating level such as building ecology (Graham, 2003), ecological design (van der Ryn and Cowan, 2007), and ecological engineering (Mitsch, 1993). In considering urban ecosystems or the design processes of buildings and cities, these approaches are all rooted in an overarching strategy that looks towards nature not just as partner, but also as 'mentor, model and measure' (Benyus, 2002, p. iii). The idea is not to impersonate nature, or to replace living systems with high-technology artificial replicas of natural systems or products as Birkeland (2008, pp. 17–18) presages, but to design with and for nature to create regions, cities and buildings that function as ecosystems, using 'Nature's designs and processes' as the basis for human designs and processes (Kibert, 2008, p. 367). Newman and Jennings (2008) take this approach further by suggesting the use of ecosystem metaphors (e.g. ecotones, patch dynamics, succession) to understand better the city form and dynamics of urban social–ecological systems (SESs), and develop appropriate design and development strategies for urban SESs.

The first strategy relies on 'designing and reconstructing ecosystems that serve human needs' by using biological species and ecosystems to do the work (e.g. clearing pollution) that in an environmental/infrastructure engineering approach would have been done by mechanical means such as scrubbers, filters and chemical precipitators (Mitsch, 1993, p. 438). This approach has been used with some success in landscape restoration and the design of regenerative ecosystems for urban greening (as described by McHarg, 1969; Lyle, 1994; Wenk, 2002); wastewater treatment (Adey and Loveland, 1991; Todd and Todd, 1993); and permaculture (Mollison, 1990).

The second strategy, ecological design, is defined by van der Ryn and Cowan (2007, p. 33) as 'any form of design that minimizes environmentally destructive impacts by integrating itself with living processes' and as 'the effective adaptation to and integration with nature's processes' (p. 34). Kibert (2008, p. 101) defines it as 'design which transforms matter and energy, using processes that are compatible and synergistic with nature and that are modelled on natural systems'. Kibert (2008, pp. 370–372) also provides a brief overview of the theoretical development of ecological design and various ecological design strategies and principles put forward by, inter alia, Yeang (1995), Bringezu (2002), Kay (2002), McDonough and Braungart (2002), and van der Ryn and Cowan (2007), as well as a list of general characteristics of ecological design. Resnick (2003, p. 44) suggests that ecological design and planning processes have four main characteristics: they are responsive to local conditions, adapt to changing conditions, employ decentralized approaches, and are developed through the contribution and collaboration of many simple entities through processes of bottom-up self-organization that follow certain generative rules (Alexander et al., 1987, p. 3). Hakim (2007, p. 88) suggests that these generative rules are developed from ethical and/or legal norms and common values (such as reciprocity) that guide the individual actions of agents. While based in local history and culture, these rules continue to change and evolve to accommodate changes in, for example, culture or technology. Their qualitative nature means that outside the laboratory of computer simulation, these generative rules cannot be reduced to mathematical algorithms that can be used to inform a master plan. Instead they are, as Hock (1999) suggests, the only effective guides to action in a 'chaordic' system.

Thus ecological design also 'invites the qualitative, the uncertain and the non-rational aspects of human nature' (Bergen et al., 2001, p. 208), and introduces goals that are focused not only on material output, but also on hard-to-quantify aspects such as connection to place, equity and aesthetics. Designing and developing new ecological technologies, buildings, municipal infrastructure systems and urban forms would thus also necessitate the development of different processes for planning, design, decision-making and delivery systems that can respond to uncertainty and the non-rational and qualitative aspects of the world. The challenge of dealing with change and adaptability is taken up by the conceptual framework described as resilience thinking (Walker and Salt, 2006, p. 11).

Resilience and regenerative sustainability

Earlier variants of sustainability envisioned a change from a current 'unsustainable' state to a future 'sustainable' state that can be achieved by following a specific set of rules. The human development enterprise would then focus on maintaining this imagined optimal state. However, the notion that, apart from a set of very specific biogeochemical conditions, there is some set of ideal 'sustainability' conditions that should be maintained is meaningless in a dynamic and ever-changing world. A number of critics (e.g. Cowan cited in Waldrop, 1992, p. 356; Bossel, 1998, p. 62; Gallopin et al., 2001, p. 12; Yorque et al., 2002, p. 436; Moffat and Kohler, 2008, p. 263) suggests such an optimal state cannot be seen as a steady-state that allows no further change. Instead, a sustainable human society is not static but would allow for growth and be 'adaptable, robust, and resilient' (Gell-Mann quoted in Waldrop, 1992, p. 351).

An increasing number of scientists are suggesting that resilience is central to determining sustainability in social–ecological systems (Brock et al., 2002; Holling and Gunderson, 2002; Walker and Salt, 2006; Brand and Jax, 2007). 'Resilience thinking' as a conceptual framework is constructed upon the idea of multiple metastable regimes separated by critical thresholds at multiple distinctive scales with cross-scale interactions (the panarchy), the importance of episodic change (leading to the adaptive cycle metaphor), and resilience. This is described as the ability of a system to move through periods of episodic change and absorb or recover from disturbances without losing its functional identity (Walker and Salt, 2006, p. 11; Gotts, 2007, p. 2). A resilience-based approach focuses on learning how to respond, adapt to and evolve with change and surprise, while avoiding changes that would move local and global social–ecological systems closer to tipping points that would threaten the life-supporting and life-enhancing capacity of these systems.

Holling and Gunderson (2002, pp. 27–28) point out that there are two different ways of interpreting resilience. The first, what they term 'engineering resilience', concentrates on maintaining stability near an equilibrium steady-state. This definition focuses on 'efficiency, control, constancy and predictability', which they see as attributes that lie 'at the core of desires for fail-safe design and optimal performance' (Holling and Gunderson, 2002, pp. 27–28). While this may be appropriate for systems with low uncertainty, aiming for these attributes in dynamic systems with high uncertainty may be counterproductive. The second definition of resilience (which they term 'ecosystem resilience') concentrates on system conditions that are far from equilibrium, focusing on 'persistence, adaptiveness, variability and unpredictability' (Holling and Gunderson, 2002, pp. 27–28). It is this latter interpretation of resilience that they consider as 'being at the heart of understanding and designing for sustainability' (p. 49).

While resilience theory is fairly well-developed in ecology, its application to the built environment has not been explored except in the area of disaster management. Pendall et al. (2010, p. 73) describe how much of current thinking about urban or regional resilience is still caught up in the equilibrium (or engineering) version of resilience that is focused on the ability of a city or region to bounce back to 'normal', i.e. to its functions and growth trajectory as it was before disaster struck. Even when disasters expose the flaws in the previous system, raising the question of whether the system should not instead be guided towards a 'new normal' (Pendall et al., 2010, p. 74), what this new normal should be is often determined by current social and institutional values, norms and rules that did not change.

The danger of promoting an equilibrium model of resilience is that systems can become trapped in a suboptimal equilibrium state as a result of increasing institutional 'lock-in' to a specific development pathway (Hassink, 2005). However, the underlying premise of the sustainability discourse is to escape the current development pathways that are building up to a combined polycrisis of environmental, economic and societal disruption if not outright collapse.

The real usefulness of the resilience framework though lies in its understanding that the collapse of a rigid system releases potential and opportunity that can be used to design new development trajectories. To make full use of the opportunity offered to rearrange the released potential into a better, more sustainable world, a more active and directed approach such as that offered by regenerative development is required.

Creating a regenerative built environment

Regenerative development (as described by Reed, 2007; and Girardet, 2010) is founded on the following philosophical departure points:

- humans, their artefacts and cultural constructs are an inherent part of ecosystems
- their actions should contribute positively to the functioning and evolution of ecosystems and biogeological cycles, enabling the self-healing processes of nature
- their endeavours should be rooted in the aspirations of the context
- development and design is an ongoing participatory and reflective process.

The ultimate goal of the built environment and the developmental processes related to it then becomes to support and enable 'the continual evolution of culture in relationship to the evolution of life' (Mang and Reed, 2012, p. 26). The regenerative development approach would lead to increasing natural and social capital that leaves 'the ecology better than before development' (Birkeland,2008, p. xv), because it 'not only preserves and protects: it restores a lost plenitude' (van der Ryn and Cowan, 2007, p. 37). Referring to this approach as eco-effectiveness, McDonough and Braungart (2002, p. 156) suggest this requires that 'instead of using nature as a mere tool for human purposes, we can strive to become tools of nature who serve its agenda too' and in the process one can produce a world of abundance. The objective of development in this version of sustainability is to create a future where people can live in mutually supportive symbiosis with their social and biophysical environment (their whole ecological system) – supporting their mutual evolution.

This last point is what differentiates regenerative design and development from the models of urban regeneration that aim to bring new life to derelict city areas through restoration and upgrading of infrastructure and an eventual gentrification of the area. Regenerative design is described by Reed (2007, p. 677) as offering, instead, a process 'that engages all the key stakeholders and processes of the place – humans, other biotic systems, earth systems, and the consciousness that connects them – [to build] the capability of people and the 'more than human' participants to engage in continuous and healthy relationship through co-evolution'.

The concept of regenerative design harks back to John Tillman Lyle who proposed that it is possible to develop buildings and cities in such a way that they regenerate lost ecosystems (Lyle, 1994). The regenerative design method itself has its roots in bioregionalism and permaculture, but has evolved since Lyle by expanding these whole-systems models of engaging with place also to include the cultural systems. Regenerative development therefore contracts with the entire social–ecological system to grow the system's capacity to evolve and increase its potential. Mang and Reed (2012) illustrate how regenerative approaches build on and integrate other sustainability approaches – such as efficient use of resources, ecological design and resilience – that lie at different 'levels of work' and which allow the physical manifestation of the regenerative potential in a system. The regenerative potential in the social–ecological system is revealed through a set of processes that engage with and integrate various narratives at different levels and scales of the system under consideration into a meta-narrative that is used to extract a vision, purpose and principles to guide the development and design process.

The regenerative process works from the macro-scale (the watershed or bioregion) to the local. It begins by reconnecting to the essence of place to provide the starting point for the design or planning process. While this involves a 'reconnection to the historical cultural, ecological, and economic patterns of a place' (Mang, 2009, p. 8), it is also 'an embodied dreaming process, in which we hermeneutically experience the phenomenon of a Place (p. 80). He sees it as both a process of building scientific understanding and a 'psycho-spiritual embedding' in the identity and aspirations of the particular context that asks:What does Nature want to be in this place? This requires looking at the context of the development intervention from an ecological scale and timeframe (which is much larger than the spatial and temporal scales of most built environment projects), to identify its unique essence or spirit of place, the functional identity of the system (its aspirations) and its potential.

The challenge is how to map this construct of place as simultaneously a spatial and a process locale described through an open system in a useful way. To get an accurate picture of all the elements in the system and the dynamics and flows between them is an impossible task that negates any reductionist attempts to build an aggregate representation of the system that can be measured and modelled mathematically. Mang and Reed (2012, p. 29) instead suggest looking for 'pattern clues' to read the landscape and the relationships comprising the system of place.

The next question is how the resident humans and their aspirations not only contribute to the story of place, but also can serve the spirit of place, enabling its regeneration and evolution. Finally, there is the ongoing process of learning and feedback, matching the development of the design or plan with the core long-term aspirations of the project, and monitoring key indicators of change. The result is a design process that 'follows a conscious processes of learning and participation through action, reflection and dialogue' (Reed, 2007, p. 678). In this way regenerative design redefines not only the design process, but also what constitutes design and who qualifies as designer. The role of the architect/ planner/designer shifts to that of facilitator of a process of revealing, rather than acting as master mind. How this plays out in practice is described in more detail in Mang and Reed (2012), Hoxie et al. (2012) and other papers in this special issue.

Discussion and conclusions

Three 'paradigms' of sustainability that co-evolved during the last half century were considered. The boundaries between these paradigms have been sharply drawn, whereas in reality they are blurred and more nuanced. What was presented in a linear manner actually occurred in parallel and with many feedback loops and iterations, as well as a considerable amount of cross-pollination.

The three paradigms share a common goal: improving the human–nature relationship so that the human enterprise can be sustained and humans can flourish. However, what differentiates the regenerative paradigm from the other two is its insistence that this can only happen if the conditions are such that all of life can flourish and continue to evolve.

The three paradigms also share a number of objectives and strategies, e.g. localized action, the efficient use of resources, reducing toxic pollution and the use of renewable energy. However, the conceptual frameworks differ significantly. The focus of the first two paradigms is on aligning the modernization project with the realities of a limited resource base and declining ecosystem services in the context of a growing global population with expectations of ever-improving standards of living.

However, it was argued that two paradigms are reaching the limitations of their usefulness. Flawed underlying assumptions, systemic inertia, and the inability fully to escape the mechanistic worldview and its limitations in dealing with complex and living systems are bringing these two paradigms to an evolutionary 'dead end'. The ideals of achieving international consensus on policies and strategies to guide local action remain trapped in international and domestic politics, meaning little real progress was achieved on issues such as climate change and the Millennium Development Goals. Ecological Modernization suffers a disconnect between an ecological mode of doing and the need for certainty, prediction and control. Nevertheless, the contribution of both these paradigms should not be negated, as they resulted in a number of new strategies, methodologies and technologies that remain of great use.

The regenerative sustainability paradigm represents a shift to the holistic living systems worldview held by many (e.g. Capra, 1997; Bossel, 1998; AtKisson, 1999; Hawken et al., 1999; Kumar, 2002, Raskin et al., 2002; Adams, 2006) as a necessary point of departure for engaging with the problems of sustainability. This paradigm attempts to address the dysfunctional human–nature relationship by entering into a co-creative partnership with nature. It aims to restore and regenerate the global social–ecological system through a set of localized ecological design and engineering practices rooted in the context and its social–ecological narratives. Further papers in this special issue explore the practical methodologies of regenerative design and the implications for design assessment (cf. Cole, 2012).

While it has a number of antecedents in the proto-environmentalist movements of the 1960s and 1970s, the regenerative paradigm still has to be tested at scale and as a fully integrated system of physical, cultural and visionary interventions. At this point the regenerative paradigm seems to offer a way for humans to engage with nature in two significant ways. It will build both the adaptive capacity to survive the perturbations of 'global change' and increase the regenerative capacity of the world to create conditions under which humans and other life can thrive. Climate change will transform global systems, creating new system rules, new stories of place and new potential. Whether a bottom-up approach is sufficient on its own or requires some further alignment with a top-down approach to reconcile the human–nature relationship remains to be seen. Only time will tell how the process of regenerative development will fare in identifying stories of place that have no historical precedent, in a social and ecological landscape where the world will literally need to be created anew.

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Endnotes

[1] This would require a book and a number of those already exist (e.g. Dresner, 2002; Edwards, 2008).

[2] Paradigm is here defined as the shared conceptual, theoretical, methodological and instrumental commitments of a community of practice (Kuhn, 1996, p. 42).

[3] The nostalgic model of New Urbanism and its twin, Smart Growth, also assumes that people will be able to afford a place close to where they work, that couples will be able to find work in the same area, that people feel sufficiently secure in their jobs to invest in nearby property, and that the community will be able to support local businesses. However, issues such as job mobility versus the flexibility to move house or move children out of schools, and the types of economic and employment opportunities on offer in these new districts often work against the ideals of a new urbanism.