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SPACE FRAME WALLS: FACILITATING POSITIVE DEVELOPMENT

Janis BIRKELAND Prof Architecture

Faculty of Engineering and Built Environment Design, Queensland Institute of Technology, Brisbane, Australia, janis.birkeland@qut.edu.au

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Summary

This paper reports on progress in developing new design and measurement concepts, and translating these concepts into practical applications. This research addresses gaps in 'best practice' green building, and is aimed ultimately at replacing green buildings with sustainable urban environments. Building on the author's previously articulated concepts of Design for Eco-services and Positive Development, this research will demonstrate how to eco-retrofit cities so that they reverse the negative impacts of past design and generate net positive ecological impacts, at no extra cost. In contrast to 'restorative' design, this means increasing ecological carrying capacity and natural and social capital through built environment design. Some exemplars for facilitating Positive Development will be presented in this talk, such as Green Scaffolding for retrofits, and Green Space Walls for new construction. These structures have been designed to grow and change over time, be easily deconstructed, and entail little waste. The frames support mini-ecospheres that provide a wide range of ecosystem services and biodiversity habitats, as well as heating, cooling and ventilating. In combination, the modules serve to improve human and environmental health. Current work is focused on developing a range of such space frame walls, optimised through an innovative marriage of eco-logical design and virtual modelling.

1. Innovations in Design and Measurement

1.1 New Design Concepts

The talk will present a range of eco-logical design concepts that are currently being developed and digitally modelled. These new design modules can create urban 'eco-services', mitigate climate change and address other sustainability issues on virtually any site, at a net resource savings. The term 'eco-services' is used here to encompass ecological health and resilience for its own sake, as well as the essential functions provided by the natural environment. With Professors Robin Drogemuller and John Frazer, and students from the Queensland University of Technology, the prototypes are being 'virtually' modelled in 3D CAD systems to optimise the modules for different applications, sites and contexts through generative feedback loops. The research will show that simple software tools can support the uptake of sustainable design within professional decision making and design processes. This digitally-supported Design for Eco-services process will facilitate further in-depth peer review and collaboration with 'green' building firms and organisations.

1.2 New Measurement Methods

New kinds of benchmarking and measurement concepts are being developed to facilitate Positive Development. These are necessary for assessing urban eco-services, and the 'positive' ecological impacts generated by the new design concept. This research aims to correct biases against sustainability that are now embedded in existing assessment tools (below). The project applies a new 'sustainability standard', where the building leaves the ecology healthier after construction than before (Birkeland 2003). With PhD students, a prototype computer-aided tool is being created to aid both the design and assessment of Positive Development projects in different urban contexts and micro-climates. User-friendly, illustrated guidelines will explain the logic underlying the new form of assessment.
2. Beyond best practice

‘Best practice’ green buildings are not sustainable. There are, however, already many isolated examples of technologies that reduce the rate of future resource consumption, compared to standard buildings - at a good return on investment (Katz 2003, Lucuik 2005, RICS 2005, GBCA 2006). There are, for example:

- Resource autonomous developments that generate their own energy and treat their own waste (Vale 2000 and 2002, Mobbs 1989)
- Building retrofits that increase worker health and productivity while saving resources (Romm 1998)
- Appliances that operate on direct solar energy, and so on (Poole 2006)

Green approaches reduce impacts, but still increase total resource flows and externalize impacts. For example, most green buildings increase the ‘urban heat island’ effect, where cities are much hotter than their regions. The 2003 European heat waves resulted in up to 35,000 deaths (IFRC 2004). To be sustainable, then, buildings must ultimately generate net positive impacts and create surplus eco-services. The foundation of the proposed research is the author’s ‘Positive Development’, whereby new construction would have net positive impacts, and compensate for embodied energy and waste. A ‘Positive Development’ is defined as that which adds social and ecological (as well as environmental) value to the urban environment by expanding both the:

- ‘Ecological base’, which encompasses natural capital, biodiversity and habitats, ecological health, and bio-security (ie the life support system)
- ‘Public estate’, as substantive democracy ultimately depends on equitable access to the means of survival

3. A pre-requisite to sustainability

As we have already exceeded the Earth’s carrying capacity, urban development that supports the ecology, as well as improving the human environment, is essential to sustainability. Ecological restoration is not enough. Sustainability cannot occur without a new kind of built environment design that generates surplus eco-services, habitats and ecosystems. Currently, built environment design drives excessive demand for materials and energy in other industries, shapes resource consumption into the future, and closes off future development options and social choices. While the built environment is central to social and ecological problems, this research will show how development can be converted into a sustainability solution (Birkeland 2002). Therefore, this research addresses the essential pre-requisites of a sustainable built environment, as follows.

3.1 A fundamental paradigm shift in green building theory and practice.

A fundamental paradigm shift in green building theory and practice is required. The concept of re-designing development to reverse prior impacts and generate net positive gains represents the next stage in the evolution of environmental management paradigms (Birkeland 2003). The theoretical stages have thus far progressed from: (a) ‘compliance’ or end-of-pipe design, through (b) ‘eco-efficiency’ or front-of-pipe design (Weizsacker, Lovins and Lovins 1997), to (c) ‘zero-waste’ or closed loop design, where waste is designed completely out of production and consumption systems (McDonough and Braungart 2002). Natural systems can replace or reduce most capital and energy intensive mechanical systems (see Beattie and Ehrlich 2004, Benyus 1997). However, the proposed paradigm will enable us to aim beyond zero waste and/or carbon neutrality to net Positive Development through (d) Design for Eco-services.

3.2 An approach that can address the scale of the problem.

Any solution must contemplate the scale of the problem. Current management approaches (eg incentives and trading) cannot address the sustainability imperative in time. Several international bodies, such as the OECD, have warned that material and energy flows need to be reduced by 90 percent within a few decades (Hasegawa 2002). Overall, the built environment generates about half of those resource flows (Roodman and Lenssen 1995). ‘Green’ buildings increase total material and energy flows. Also, only 2-4 per cent of the building stock is new each year, and half of building energy is embodied in construction itself. So even if all new buildings were ‘green’, they would only address 2 percent of 20 percent energy flows (ie .04), and would still have other negative impacts. Due to the material and energy flows in existing buildings then, ‘eco-retrofitting’ of cities is a pre-requisite to sustainability. The proposed retrofitting concepts support this imperative, as they can be adopted and replicated virtually anywhere on a large scale. They can also be applied in new buildings.
3.3 A practical strategy for implementing eco-retrofitting.

The research offers a practical strategy for implementing eco-retrofitting as well. Eco-retrofitting has already proven to pay for itself in human and natural resource savings, while generating employment and low-risk investments (Romm 1998). Any extra R&D and construction costs can be recovered from the net resources savings and capital gains in a short period of time (Edwards 1998, Katz 2003). Retrofits of commercial buildings bring substantial savings and increased worker health and productivity, while reducing externality costs as a whole (Hargroves and Smith 2005, Esty and Wilston 2006). For example, the market value of a retrofitted home, on average, instantly increases more than the cost of the retrofit (US EPA 1998). Indeed, investments in greening buildings compare favourably with investments in stock and bonds (Romm 1998). The savings from water, energy and material efficiencies will increase as their true costs are eventually reflected in their price (see Meyers and Kent 2001). While the contemporary approach is to rely on indirect and hence unpredictable incentives, this project will harness market forces towards ‘direct action’.

3.4 New design and measurement concepts for the conversion to Positive Development.

New design and measurement concepts are required to support the shift to Positive Development. Although eco-retrofitting would cost society less than doing nothing, ‘best practice’ exemplars and tools will not drive the fundamental systems change in the construction industry that is needed. Current environmental management and assessment tools are biased against eco-retrofitting (Drogemuller 1999), as well as ecological sustainability (Birkeland 1993). In fact, sustainability is deemed to be ‘addressed’ by tools that simply predict, measure and trade off negative economic, social and environmental impacts to reduce relative future harm. Because our computational tools focus on negative inputs and outputs, they encourage change at the margins. Further, they do not take into account the unique nature and intrinsic value of living things. They reduce complex, location-dependent, living ecosystems to generalized resources and impacts. The focus has been on impacts (ie measuring symptoms) rather than design (ie identifying causes and solutions). The proposed approach would address significant systemic biases in building design and assessment tools (below).

3.5 New methods for increasing positive impacts at the building and urban scale.

This research aims to develop new methods for increasing net positive impacts at the building and urban scale. There are myriad measurement methods for buildings, but they largely ignore eco-services and ecosystems. Ecosystem goods and services refer to natural systems that, for example: support biodiversity and productive ecosystems; treat organic wastes; sequester carbon; control pests; produce food, fibers, and pharmaceuticals; help regulate the local (and global) climate; develop fertile soils and prevent erosion; purify air, store and recycle water; and alleviate floods, drought and storm water runoff (Daily and Ellison 2002). The term has been used to refer to human benefit only. Thus we need a term that includes ecosystem health, resilience and integrity, or ‘eco-services’ (ie not just ‘good and services’). Existing methods indirectly encourage the substitution of ecosystems by built and manufactured capital. The proposed approach would replace fossil fuel driven machines with natural systems.

3.6 Contribution to building information modeling (‘BIM’).

Finally, this research will contribute to building information modeling (‘BIM’). The construction industry is rapidly moving towards BIM. It provides a single information model for ‘real time’ information exchange between participants in the building design and construction process. At present, however, BIM cannot deal with crucial sustainability issues like embodied energy, greenhouse gas emissions, biodiversity and health. The project is contributing to, and benefiting from, current work at QUT, led by Professors Robin Drogemuller and John Frazer, toward better integration of BIM and virtual modelling to support more sustainable design and construction. This research project is essential to ensuring that such technical advances in the building industry integrate deep sustainability principles and criteria.

4. Sample space frame modules

The primary advances provided by this project are: a) design for eco-service concepts and prototypes and b) eco-service measurement concepts and tools. This project will show that net contributions to the ecology, as well as society, are possible through development itself, despite unavoidable ‘ecological waste’ (Birkeland 2007b). Two generic prototypes are illustrated here: a) Green Scaffolding for eco-retrofitting, and b) Green Space Wall for new buildings. These generic types are briefly presented before the discussion about how they address sustainability issues and represent an advance over what is now called ‘green building’ design.
4.1 Green Space Wall

The Green Space Wall is an ecosphere that doubles as an exterior wall or mixed interior/exterior spaces in new development. Despite the unavoidable resource flows embodied in new construction, there will always need to be new buildings, which currently have significant embodied waste. New building can, however, reduce the impacts of the urban areas by substantial positive on-site and off-site ecological gains. These walls can create multiple, synergistic uses of space. For example, they can generate clean energy, air, water, food and soil - while providing social space. This approach contrasts with many 'green buildings' which minimize space to reduce the additional resource flows and negative impacts created by conventional materials and forms.

Figure 1  Example of new building using a Green Space Wall

4.2 Green Scaffolding

Green Scaffolding applies mainly to eco-retrofitting. It essentially wraps a light weight structure around the exterior of existing buildings to provide the full range of climatic and ecosystem functions. Such ecospheres are low in embodied energy and waste, adaptable, demountable and portable. Similar modules can also be installed in public spaces, or over some streets and parking structures, to contribute aesthetic and social values while increasing urban eco-productivity.

Figure 2  Example of eco-retrofit using Green Scaffolding

5. Advances in design

These design innovations address basic omissions in ‘best practice’ green building design, by providing for the expansion of: (a) natural functions in urban systems to improve the ecology and eco-productivity of cities, (b) the integration of infrastructure and ‘ecological space’ for ecosystem re-generation with less
net land cover, (c) the provision of eco-services to reduce mechanical equipment, fossil fuels, the urban heat island effect, etc, described below.

5.1 Improving eco-productivity and urban ecology

Green Space Wall and Green Scaffolding can increase the eco-productivity and ecology of cities. Design has largely ignored the need to design for nature, in addition to design for people. At best, green design aims to design with nature or like nature, and generally adds passive or active environmental controls onto a non-sustainable building archetype. This is partly because, in the name of ‘efficiency’, architectural spaces have sometimes been segregated and minimized. For example, contemporary best practice, ‘double-skin’ buildings reduce energy consumption, but create ‘dead’ spaces, adds costs, and increase the urban heat island effect. Design for Eco-services, in contrast, increases and optimises space for both social and natural functions.

5.2 Integration of infrastructure and ecological space

Green Space Wall and Green Scaffolding integrate infrastructure with ecological space to support ecosystem regeneration and productivity. Integrated ‘whole systems’ design approaches are understood to provide more efficiency gains per dollar because they create positive synergies, rather than trade-offs (Hawken, Lovins and Lovins 1999). However, conventional eco-retrofitting concepts have not been fully integrated with the structure, so they can add to construction costs even though saving resources. In the proposed prototypes for retrofitted and new buildings, the structure and eco-services themselves replace many high maintenance and fossil-fuelled mechanical systems. Being integral with the structure, they can prolong the functional and structural life of buildings. More importantly, this approach can improve ecosystem and human health, and universal access to the means of survival (eg food, heat and water).

5.3 Provision of multiple eco-services

Green Space Wall and Green Scaffolding aim to demonstrate means to overcome certain common deficiencies in green building. These are reflected in the proposed design of the Australian National Sustainability Initiative (Figure 1). The proposed sustainability learning centre will demonstrate a whole new typology of architecture that creates net positive ecological and social impacts. A lightweight, demountable space frame structure supports a Green Space Wall, composed of double-skin ecospheres. These modules create a variety of ecosystem goods and services (‘eco-services’) as well as providing environmental control functions. The modules not only heat, cool and ventilate the building, but produce clean energy, air, water and soil. Depending on the orientation and other functions, the exterior Green Space Wall would contain, for example:

- Vertical landscapes for water and air purification
- Habitats for small animals (eg frogs, beetles, lizards) that can be viewed from inside
- Sail and shade cloths designed for circulating cool air as well as providing shade
- Solar stacks and shower towers integrated into the vertical truss structure
- Bird and possum nests, fish ponds and butterfly breeding areas
- Pipes for exterior mists (cooling and fire prevention) integrated in the vertical truss
- Internal Trombe walls (from local construction rubble) for thermal rock storage
- Vertical composters and worm farms that are visible to building users
- Living machines to treat grey water and even sewage (in sealed modules)
- Light weight vertical wind turbines integrated with vertical structural truss
- Corridors, external walkways and/or decks that move through some modules

The next stage is to quantify and test the positive contributions to social and ecological sustainability made possible through this new design approach.

6. Biases in measurement

The project will apply new measurement concepts, to the design of a new computer-aided tool to quantify and assess Design for Eco-services. Just some of the problems with existing methods that the tool will address are listed below (Birkeland 2008):

- Traditionally, environmental planning and management has only tried to measure negative impacts, even though this is - by definition - impossible in a ‘complex system’ (Birkeland 1993). Predicting negative impacts requires an understanding of bioaccumulation and the interactions of toxins with
immune systems. In contrast, development that did no harm would only need to be a good investment. Yet most assessment tools do not even count positive ecological impacts. The new tool will put net positive ecological and social gains on an equal footing with the relative reduction of future negative impacts and risks.

- The economic costs of environmental damage that conventional development will have in the future are downplayed in assessments, due to the inherent difficulties of predicting and measuring open systems. Yet many assessment methods do not even count the economic benefits of an undisturbed natural environment. They apply a meaningless relative standard, comparing green building to ‘typical’ buildings of the same kind, rather than to ecological conditions existing prior to any development (the author’s ‘sustainability standard’). The new tool will put the economic benefits of a healthy environment on an equal footing with the economic costs of green development.

- Most assessment methods favour existing, fossil-fuel driven, industrial processes and non-sustainable building types, in that their impacts are treated as ‘normal’. An eco-retrofit or innovation is expected to pay back its costs (and sometimes even its embodied energy) whereas standard building equipment usually does not. That is, mechanical equipment is not seen as costing ‘extra’, even though they require regular maintenance, repair, spare parts and specialist mechanics. The new tool will put passive systems on an equal footing with fossil fuel equipment.

- Because our measurement methods treat current urban conditions as a neutral baseline, rather than negative, we usually only count the costs that will be incurred from this point on. Thus, our tools not only count the ‘sunk cost’ in existing systems, they exclude the ‘opportunity cost’ of poor design. To overcome this bias against eco-retrofitting, the benchmark should be the pre-development ecological conditions on the site. Thus we would compare both the original building - and the proposed retrofit - to pre-development conditions (ie sustainability standard). The new tool will put eco-retrofitting on an equal footing with new construction.

- As ecosystem services cannot be directly measured, ‘surrogates’ have always been used to enable quantification, such as the area of wetlands or volume of biomass (Heal 2000). However, such surrogates usually only look at one or two values of natural systems, such as carbon sequestration or water purification. Even holistic concepts like ‘ecological footprints’ can really only measure a reduction in relative negative impacts. Therefore designers do not try for multiple and surplus eco-services (Birkeland 2007a). The new tool will put the expansion of ecosystems on an equal footing with resource conservation and efficiency measures.

- Our conventional building assessment and rating tools do not assist in design as a creative process. Most, if not all, so-called ‘design tools’ only measure pre-conceived designs. Further, their measurement concepts are based on, and thus perpetuate, conventional building typologies. This project will provide means to help designers to create something that does not yet exist. That is, to ‘design’. The new tool will put creative design processes on an equal footing with reductionist analyses.

- Because assessment methods treat complex living ecosystems as mere resources, this ‘legitimates’ the substitution of natural for built and manufactured capital. Reducing the ecology to mere inputs and outputs conceals the need to increase ecosystem integrity and environmental flows - not just reduce consumption. Our current tools also discount the future by, among other things, not counting the time and cost of replacing living ecosystems or ‘ecological waste’ (Birkeland 2007b). The new tool will put ecological time on an equal footing with financial time.

- Our assessment methods do not consider how conventional development can transfer resources and increase disparities of wealth over time. Equitable concepts like ‘environmental space’ (ie the available renewable resources divided by the relevant population) are not yet applied to built environments. New concepts are also needed like ‘negative space’ to reflect the distributional impacts resulting from the conversion of (public) land and natural capital to private development. The new tool will put the distribution of resources, including space and access to the means of survival, on an equal footing with the distribution of negative impacts.
7. Biases in assessment

The ‘DNA’ of current assessment and rating tools - based on input-output accounting rather than design - encourage marginal improvements to an unsustainable archetype. They act as a barrier to Positive Development. Design tools need to be very different than current approaches. The design concepts and measurement tools will help us move beyond green buildings to sustainable ones. Some biases to be overcome include (Birkeland 2008):

- From retrospective analysis to future-oriented design. The analysis of the predicted impacts of a proposed design can reinforce old forms and patterns of development at the expense of forward-looking processes that seek to value add and create new synergies.
- From impact reduction to impact reversal. The emphasis on mitigating negative impacts can be at the expense of eco-innovations that seek to improve social and ecological conditions through positive off-site and on-site impacts and health improvement.
- From building on templates to changing underlying concepts. Tools that encourage incremental modifications to conventional building templates can delay or prevent the re-design of basic infrastructure, spaces and forms that would increase the ecological base.
- From universal engineering to natural systems solutions. The perceived need to reduce everything to numbers can lead to mechanistic approaches that exclude the ecology, because natural systems defy simplistic measures (being complex systems).
- From aggregating impacts to mapping flows. Analyses that aggregate measurements to get a point value can obscure the potential for whole systems efficiencies to positively affect total resource flows by creating synergies among systems on different scales or levels.
- From sequential and segmented processes to integrated ones. The focus of LCA-based analyses on inputs and outputs of processes at separate stages during the construction process can encourage sub-optimal changes at the expense of rationalizing the whole supply chain.
- From data-driven indicators to implementing change. Overvaluing factors that we have data for can come at the expense of mapping systems dynamics to find better means of meeting needs or better ‘leverage points’ for generating positive ripple effects throughout the system.
- From an individual project to a contextual perspective. The focus on the efficiency of individual buildings and their components can be at the expense of rethinking buildings in relation to their context to improve social, structural and ecological deficiencies of the urban area.
- From fossil fuel reduction to a shift to solar resources. The emphasis on energy reduction through efficient use of fossil fuels distracts attention from means to convert to healthier sources of energy, and tends to lead to ‘under-design’ of passive solar systems.
- From reducing space to value adding space. Pseudo-efficiency and cost reduction through zoning and minimizing spaces in buildings can come at the expense of optimizing spatial resources by simultaneously accommodating human activity in viable ecosystems.
- From reductionist accounting to design reporting. Reductionist analyses can lead to tradeoffs between positive and negative factors at the expense of holistic design processes that explore wider options with the aim of increasing social, natural and economic capital.

Processes which frontload ecological design can help to overcome the inherent biases in our current assessment and measurement tools.

Conclusion

The transition to development that increases sustainability (rather than reducing negative future impacts relative to standard buildings) will require radically different design and assessment concepts and tools. The paper has provided a brief overview of progress toward new design and measurement processes presaged in *Positive Development* (Birkeland 2008). The talk focuses on design concepts and eco-technologies that can facilitate Design for Eco-services.

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