ABSTRACT

Governments, industry and the communities are developing a consensus that the current pattern of human activity is ecologically unsustainable, and that this must change.

The paper explores issues that will need to be resolved for a successful sustainable tall building of the Third Millennium. This will not just incorporate sustainable features, like energy efficiency, but a more fundamental change in the systems – technical, economic, organisational – involved in delivering the project, not to mention re-defining the project itself. The role of externalities also needs to be addressed.

Any project is shaped by constraints, which are part of the creative process. In a sustainable building the constraints need to be identified to allow the imaginative solutions to be developed.

To achieve fundamental changes in delivering a tall building project will require strong drivers. These do not exist, as the development of a project is fragmented between the developer and end user. As companies with a deep commitment to sustainable development begin to appreciate that their accommodation represents a significant component of their ecological footprint, then they will need to look more carefully at the supply chain that delivers that accommodation, and seek to influence it to ensure a sustainable outcome.

INTRODUCTION

High buildings and high density living have gone together since the earliest days of urbanisation, though the driving forces leading to such urban form have varied from time to time and place to place. For much of human history security has been a dominant issue shaping the urban environment. Defence of civil society (and its livestock and artefacts) against a hostile and lawless countryside saw the formation of defensible walled cites and sometimes within these there were hostile competing forces (see the tower palaces of northern Italy\(^1\)). It could be that the corporate fortresses of the present day are the symbolic successors of these imperial fiefdoms\(^2\).
At modest densities, of up to a few hundred persons per hectare, low rise constructions can serve. As density increases, however, or as the expectation for space per person increases so too does the demand for higher buildings.

Physical security is no longer the determining influence of urban form. Within the urban context, the growth in popularity of tall buildings (both number and height) is now mainly driven by economics and demographics, as business location is a strong determining factor as is the scarcity of land in urban centres.

The evolution of the tall building has been shaped by a range of restraints. Principally these are economic, technological, social and basic environmental constraints, with the last mentioned often governed by regulatory requirements, such as over-shadowing and more recently with the need to maintain a high level of internal air quality. Architects have worked within these constraints to generate innovative and imaginative solutions. The main changes over the last hundred years have been improvements in technology, which have allowed skyscrapers to reach new heights.

The tall building of the twenty-first century will need to address new environmental constraints of an order not yet fully realised, which, like previous challenges, will stimulate new creative solutions.

Systems such as financial analysis, procurement methods and project management, have been introduced to efficiently address current constraints and deliver a profitable product. In addressing new environmental constraints, these institutionalised systems also need to be reviewed to see how they can be adapted to produce a sustainable tall building of the Third Millennium.

THE NEED FOR A SUSTAINABLE BUILDING

In many areas of development, particularly since the Industrial Revolution, the main challenges in delivering tall buildings have been seen in technological terms, and working within an economic paradigm that assumes continuous growth. However natural systems provide a boundary to such growth, which is only now being appreciated.

There is now a better understanding that the main input into economic growth is natural capital. Growth is therefore limited by the ability of natural systems to provide ecological service in a sustainable manner. It is conservatively estimated that the economic value of ecological services produced by the Earth is of the order of $US33 trillion per year.

Like any business that depletes its capital to generate profit, if humans continue to utilise natural capital at a greater rate than it can be replaced by the biosphere, then the operation is unsustainable, and current profits will be a temporary aberration. As natural capital is depleted the Earth will be threatened by bankruptcy. Unfortunately, natural capital has not been adequately valued, which has meant that there is an economic incentive to exploit it unsustainably.

The World Wide Fund for Nature has estimated that the Earth’s natural ecosystems have declined by about a third over the last 30 years while the ecological pressure of humanity on the Earth has increased by about 50 per cent over
the same period. As the destruction of natural capital exceeds the ability of the biosphere to regenerate itself, considerable effort and change will be required to achieve a sustainable world. One estimate suggests that materials consumption will need to be reduced by half worldwide and by forty times in developed countries.

A response to this environmental crisis has been incorporated into the concept of ecological sustainability development, which was introduced by the former Prime Minister of Norway, Gro Harlem Brundtland, when she headed the World Commission on Environment and Development. That Commission defined sustainable development would be: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

The concept of sustainability requires fundamental changes to how business is done. It moves away from the simple idea of environmental protection, which involves avoiding doing direct harm. Instead it seeks to reduce the ecological footprint of human activities. It has been estimated that the global ecological footprint increased by 50% between 1970 and 1997, a rise of about 1.5% per year. This data supports the conclusion that natural capital is being unsustainably eaten up to support human activities.

While there is no specific data on the ecological footprint of tall buildings, it has been estimated that building inputs consume 40% of raw materials, 36–46% energy and take up 20–26% of landfills. Finally, the shape of our cities is influenced by commercial centres, where tall buildings predominate, and therefore their footprint also needs to include infrastructure such as the transport system which delivers people to their workplaces.

**DEFINING THE SUSTAINABLE BUILDING**

Architects have taken the lead in incorporating the concept of sustainable development in their principles, and in practice.

According to Robert Berkebile, founding chairman of the Committee on the Environment (COTE) of the American Institute of Architects, sustainable building design is an act of restoration and renewal, contributing to the social, economic and environmental vitality of the individual and of the community.

Translating such aspirations into design outcomes, William McDonough formulated a set of principles for sustainability of the built environment now known as the *Hannover Principles*. They are:

1. Insist on the rights of humanity and nature to coexist in a healthy, supportive, diverse and sustainable condition.

2. Recognise interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognise even distant effects.
3. Respect relationships between spirit and matter. Consider all aspects of human settlement, including community, dwelling, industry and trade, in terms of existing and evolving connections between spiritual and material consciousness.

4. Accept responsibility for the consequences of design decisions upon human well being, the viability of natural systems, and their right to coexist.

5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance of vigilant administration of potential danger due to the careless creation of products, processes or standards.

6. Eliminate the concept of waste. Evaluate and optimise the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste.

7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.

8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled.

9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

To develop these principles, McDonough has teamed up with Michael Braungart. Together they have analysed how materials can be cycled through the biological or a technological metabolic process, ideally without down cycling from higher grade to lower grade products. They argue that material flows must now become cradle-to-cradle.

In the literature there is a significant body of information on technologies to support these design principles, often demonstrating that extra construction costs are offset by reduced running costs.

PARADIGMS

The ability to identify paradigms is important if existing practices that operate against achieving a sustainable building are to be challenged, and creative responses developed.
It is therefore useful to contrast some of the assumptions of various aspects of the creation and use of a conventional tall building with that of what we might expect of a sustainable building. Inevitably this is a coarse approximation, but the contrast between the two sets of expectations provides a useful starting point from which to challenge existing assumptions and paradigms.

<table>
<thead>
<tr>
<th>The Issue</th>
<th>For a Conventional Building</th>
<th>A Sustainable Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits</td>
<td>Physical constraints</td>
<td>Ecological constraints</td>
</tr>
<tr>
<td></td>
<td>Cultural constraints (eg planning)</td>
<td>Resource limitations</td>
</tr>
<tr>
<td></td>
<td>“Height matters”</td>
<td>“It’s not height that matters, it’s what you do with it”</td>
</tr>
<tr>
<td>Relationship to natural capital</td>
<td>Parasitic, using natural capital with a net deficit</td>
<td>Synergic, both using and contributing to natural capital with no net deficit</td>
</tr>
<tr>
<td>Design objectives</td>
<td>Economically viable investment</td>
<td>Sustainable life support system</td>
</tr>
<tr>
<td></td>
<td>Public statement</td>
<td>Interactions (eg transport, staff, materials, wastes)</td>
</tr>
<tr>
<td></td>
<td>– place of importance</td>
<td>Involving occupants in sustainability mission</td>
</tr>
<tr>
<td></td>
<td>– visibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meet basic standards of habitability</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Interactions, in which business-to-business and business-to-customer proximity are prime criteria</td>
<td>Efficiency of access (people, goods, support systems)</td>
</tr>
<tr>
<td>Shape</td>
<td>Statement</td>
<td>Harvesting resources (eg air, light, water, visual amenity)</td>
</tr>
<tr>
<td></td>
<td>Maximum useable floorspace</td>
<td></td>
</tr>
<tr>
<td>Fabric</td>
<td>Economic constraints (capital cost)</td>
<td>Provision of services (eg air, light, view)</td>
</tr>
<tr>
<td></td>
<td>Conventional aesthetics</td>
<td>Aesthetics of a sustainable culture</td>
</tr>
<tr>
<td>Technology</td>
<td>Comply with standards, based on conventional practice</td>
<td>Outcomes focus based on best practice, such as employing innovative ways to maximise effectiveness of resource use</td>
</tr>
</tbody>
</table>
This list is not exhaustive, and other similar lists exist\textsuperscript{22}. However it is presented to illustrate the mental changes that will need to happen for those currently producing conventional buildings if they are to produce the sustainable building that will be required in the future.

### FRAMEWORK FOR THE SUSTAINABLE BUILDING

There is considerable difference between a sustainable building and a building with sustainable features. The two are often confused, with most projects being in the second category.

<table>
<thead>
<tr>
<th>The Issue</th>
<th>For a Conventional Building</th>
<th>A Sustainable Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use</td>
<td>Fixed at the time of hand-over managed turn-key systems</td>
<td>Subject to ongoing environmental management, custom fitting, re-fitting and maintenance, Active environmental management</td>
</tr>
<tr>
<td>Economics</td>
<td>Focus on initial capital cost Rate of return on investment</td>
<td>Total life cycle evaluation</td>
</tr>
<tr>
<td>Management</td>
<td>Fragmented between developer, owner and lessees</td>
<td>Total asset management\textsuperscript{21}</td>
</tr>
<tr>
<td>Personal Space</td>
<td>Generalised De-personalised</td>
<td>Recognition of workplace conditions as business-specific fundamental</td>
</tr>
<tr>
<td>Social</td>
<td>Ignore</td>
<td>Quality of life Use of time</td>
</tr>
<tr>
<td>Externalities</td>
<td>Compliance with regulations and codes, with no responsibility taken for outcome</td>
<td>Incorporated into planning and development phases, with focus of maximising outcomes</td>
</tr>
<tr>
<td>Effectiveness measures</td>
<td>Based on return on investment, usually capital component. Also includes the rentability of the building.</td>
<td>Measures the effectiveness of the building on its ability to cost effectively deliver staff productivity and reduce the ecological footprint</td>
</tr>
</tbody>
</table>
A sustainable building requires more than identifying solutions to specific problems, but changes to attitudes, paradigms, processes and systems to deliver the project. If the process of identifying suitable technologies is not done within a systemic framework, it becomes piecemeal and may even become tokenistic as specific solutions are lauded, while, overall, the sustainable performance of the building is poor. The principles enunciated above provide a useful guide, though providing little information on how they can be translated into a building with truly sustainable outcomes.

In looking at the processes that currently are involved in delivering a tall building, it is little like being with Alice in Wonderland, as she chats to the Cheshire cat:

“Would you tell me, please, which way I ought to go from here?”

“That depends a good deal on where you want to get to,” said the Cat.

“I don’t much care where –”, said Alice

“Then it doesn’t matter which way you go,” said the Cat.

“– so long as I get somewhere,” Alice added as an explanation.

“Oh, you’re sure to do that,” said the Cat, “if you walk far enough”.

Unless there is a common objective in a tall building, beyond being “tall”, then it is not surprising that projects lack direction in comprehensively addressing the objective of sustainability.

Current systems are characterised by the following features:

- Rigid processes and procedures;
- Clear demarcation between professional “silos”;
- Controlled (and limited) engagement between “silos”;
- Fragmentation of problem solving;
- High level of automation, with heavy reliance on standards to define design features and services; and
- Disincentives for professionals to produce energy and resource efficient outcomes.

Institutional inefficiencies in various components of a project are described in more detail by Lovins and Hawkins et al.
Few projects are defined in terms of sustainable outcomes, which is not surprising with the structure of the industry that is fragmented between developer, financier, designer, construction team, lessee, lessor and facilities manager, each with their own objectives. It will take some significant changes in the relationships between the various stakeholders in the “assembly line” that produces a tall building to achieve such a common goal, which is an essential pre-condition for delivering a sustainable tall building.

Once a goal based on sustainable development is in place then it is possible to develop more detailed objectives for a sustainable tall building and performance measures by which it can be assessed.

Existing systems and processes will need to change to bring together the various components of the project, so that financial and professional inputs are aligned with the sustainability goals of the project.

Translating the sustainability goals and objectives into design and construction specifications will require significant changes in the framework by which problems are solved.

There are a number of such frameworks available. The one that has gained the most widespread acceptance is The Natural Step (TNS), developed by Karl-Henrik Robèrt as it is grounded in fundamental scientific principles. They are summarised into four system conditions:

Nature is not subject to systematic increasing:

1. concentrations of substances extracted from the Earth’s crust
2. concentration of substances produce
3. degradation by physical means
4. human needs are met worldwide

TNS has been effectively used in the construction of the University of Texas Health Science Centre, resulting in a reduction of energy usage by 30%, installation of a graywater system to reduce water consumption and ensuring that a high level of recycled materials were incorporated in the structure.

TNS not only identifies direct impacts of activities and materials used on a project, but considers supply chain issues such as whether timber is sourced from a sustainable harvesting operation. It is a structure to identify the nature of sustainable solutions rather than delivering applied solutions.

To complete the process it is useful to combine TNS with other analytic tools such as Cleaner Production, Industrial Ecology and Dematerialization, where a range of case examples demonstrate the effective deployment of technologies that can be used to address the issues raised by TNS.
One of the advantages of aligning various stakeholders involved in a project is the lack of common language in which to communicate what it means to deliver a sustainable tall building. TNS provides such a common language.

**CONCLUSION**

Ken Yeang has incorporated the principles of sustainability in his “bioclimate” skyscrapers. His buildings seek to create a place responsive to local climate and able to deliver a high level of comfort for occupants. In achieving these ends he makes innovative use of natural light and ventilation and of internal ecologies such as sky courts and vertical landscapes.

However such examples are few, although many buildings do incorporate elements sustainability, this is often done in a piecemeal manner.

There is a trend emerging where corporations are likely to take more interest in performance of their accommodation in terms of sustainability, to address commitments made in their environmental policy.

While the end user often has little impact on the supply chain that delivers a tall building for their use, this has occurred in other industries such as motor vehicle manufacturing. Top-down decision making will not be replaced by bottom-up, but decision making at all levels and all along the supply chain is likely to be increasingly susceptible to community expectations on sustainable development.

While this paper has addressed some of the processes and drivers that could be used to deliver a sustainable tall building, it has not addressed the question of we will have tall buildings in the Third Millennium. While there is little value speculating about this question, what can be said with some certainty is that unless we learn to work within the ecological restraints of nature, then the tall building will have no future.

**ACKNOWLEDGMENTS**

The authors would like to thank Virginia Kneebone (VK+Assoc), Ros Magee (Spowers) and Rives Taylor (University of Texas – Houston) for their assistance in preparing this paper.

**REFERENCES**

1. Fernández-Armesto, F, *Millennium: A History of our Last Thousand Years*, Black Swan, 1996. See Figure 5.10 which shows the towers of San Gimignano dominating the skyline.

2. The link between Medieval Verona and a modern American city was made by Baz Luhrmann in his film *Romeo + Juliet* (Twentieth Century Fox, 1996). In his contemporary update of Shakespeare’s classical story, the Montagues and Capulets are represented in the first scene as
aggressively competing companies, with their names emblazoned on the front of their corporate skyscrapers.

3 This is known as the sick building syndrome, and relates to the circulation of contaminants such as radon, formaldehyde and bacteria within the built environment. Most indoor air pollution comes from sources inside the building. For example, adhesives, upholstery, carpeting, copy machines, manufactured wood products, cleaning agents or biological agents via the air conditioning and ducting system.


5 Natural capital has been defined by Herman E Daly in Beyond Growth (Beacon Press, Boston 1996) as being functions and services provided by the biosphere, such as ecosystem goods (such as food) and services (such as waste assimilation) which represent the benefits human populations derive, directly or indirectly. When natural capital is used, often at minimal charge, and combined with manufactured and human capital services it is integral to contributing to human welfare.


7 Two examples of collapse of different parts of ecological systems can be illustrated by experience with fish stocks in different parts of the world. Falling stocks of cod in the North Sea, possibly linked to Greenhouse warming, resulted in quotas being instituted in 2000 (see Casey J “Prospects poor for North Sea cod”, Fishing News, 8 October 1999). A similar collapse in cod occurred off Newfoundland in 1992, which was mainly due to over exploitation of the resource (see Haedrich R L and Hamilton L C “The fall and future of Newfoundland’s cod fishery”, Society and Natural Resources, 13:359–372, 2000). Both examples illustrate the link between economic and natural systems.

8 Costanza et al, op cit.


12 The ecological footprint is a convenient indicator of the amount of land and resources people impact by their production and consumption behaviours. In doing so the footprint demonstrates the connections between local behaviour and environmental quality across the earth. The footprint is a measure that relates any activity that processes energy and materials by relating it to an area or volume of land, sea and atmosphere that is necessary to support that activity. Usually expressed in hectares per person the ecological footprint is used as a comparative tool for assessing the sustainability of a given geographic area. For example, were the rest of the world to operate at the level of environmental impact of the US we would need three planets with the regenerative capacity of Earth. For more background on this concept see Wackernagel, Mathis and Rees, Our Ecological Footprint: Reducing Human Impact on the Earth (New Society Publishers, Gabriola Island, BC, Canada, 1996).


21 Total asset management is defined as including all management initiation, processes, investment analysis, project management (including design, procurement and construction) and facilities management.


23 A number of companies have been accused of “Greenwashing”, where they publicise ephemeral achievements while continuing to conduct their business unsustainably, and sometimes causing significant harm to the
environment. For more details see Kenny Bruno and Jed Greer, book *Greenwash: The Reality Behind Corporate Environmentalism* (Penang, Malaysia: Third World Network. 1996)


28 The Natural Step is based on the principles of thermodynamics. It argues that the biological and other elements of the biosphere that have evolved together and over a long period of time have established an effective working arrangement on which the biosystems are now dependent.

29 University of Texas, *Sustainability Report* 200.

30 Cleaner production is the continuous application of an integrated preventive environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment. It includes the conservation of raw materials and energy, the reduction of toxic raw materials, and reduction of the quantity and toxicity of all emissions and wastes.

31 Industrial ecology is an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems.

32 Dematerialization is the process by which lesser amounts of material are used to make products or perform the same function as their predecessor.


34 Through the vehicle of ISO 14000 certification, large motor vehicle manufacturing corporations are requiring companies that supply them to also be ISO 14000 certified. This requirement has seen large companies requiring their suppliers to also be ISO 14000 certified.