SUSTAINABLE DESIGN IN COMMERCIAL BUILDINGS

Construction Industry Institute, Australia Inc.
Jon Robinson, Professor of Property and Construction
The University of Melbourne

Published by
Construction Industry Institute, Australia Inc.
Queensland University of Technology
2 George Street
BRISBANE QLD 4000

Phone: 07-3864 2811
Facsimile: 07-3864 1170
Abstract
A research proposal is discussed to measure the outcomes of incorporating sustainable design features in commercial buildings. A past project is described as background; it investigated a range of property and construction options using standard life cycle costing methodology. Commercial buildings are significant users of energy and the resultant greenhouse gas emissions in carbon dioxide equivalent are quantified in order to assess how it may be absorbed by forest creation. A ratio of built floor area to forest acreage is established. A research proposal is outlined; it consists of a comparison between two new office buildings of similar design, quality, configuration, specification and location but with major differences in the provision of sustainable design features.

Keywords
Sustainability, life cycle costing, research, energy, carbon footprint.

INTRODUCTION

The holistic nature of environmentally sustainable development is not well understood by the property and construction industry. Many operators in the industry tend to concentrate on a component of environmental sustainability. Energy use and heritage conservation have been popular proxies for environmental sustainability for some years. In very recent times, it has become fashionable to market or advertise a proposed building as being environmentally sustainable if it includes a design feature such as a façade containing photovoltaic cells. The use of environmental marketing occurs even if the building itself breaks most of the environmental sustainability rules in terms of its configuration, materials and services.

Building design and the delivery process is critical to the environmental performance of buildings. In Australia, buildings are responsible for 30% of all raw materials used by society and they consume more than 40% of all energy produced causing more than 40% of all air emissions. It is expected that the commercial building sector will double its greenhouse emissions over the next decade. So there is a significant opportunity to establish some environmental sustainability benchmarks.

In late 1999, the research project titled “Sustainable Built Asset Management” was initiated by the Construction Industry Institute Australia (CIIA) and the University of Melbourne (UoM). The project comprised a scoping study and CIIA made funds available to establish a research team and work on the research proposal. The progress of the project was reported to CIIA during 2000 and 2001 (Aye et al 2001). The project was developed into an application to the Australian Research Council (ARC) for a Linkage Grant for 2003-2005. This follows a SPIRT Grant in 1998-2000 to investigate ESD in commercial buildings.

The purpose of this paper is to first, provide a background consisting of a brief description of parts of the SPIRT project and second, to outline the proposed Linkage project.
BACKGROUND

Environmentally sustainable development
The SPIRT project consisted of a study into the specification, modelling and post-construction performance measurement of an environmentally designed ecologically sustainable commercial office building. The project was scheduled to be of approximately three years' duration. Broadly, the first year was to comprise the selection of a suitable location and the pre-design and design work; the second year to comprise contract documentation and construction and the third year to comprise the commissioning of the works and then occupation and performance measurement of the new premises.

The project involved two industry partners, one that was intending to seek new accommodation for its activities and the other that had special abilities in environmentally sustainable development. The research project consisted of two main elements: first, background research work and second, the recording of the property development process from inception through to the ultimate commissioning and occupation of the new building to enable the performance of the building to be assessed. As a result of commercial pressures, the first industry partner elected not to proceed with the project as developer. It reached a decision that it would prefer not to own its own premises; rather it has decided to lease the premises from a developer.

In the event, a developer came forward to take over the commercial project from the first industry partner. As a result of these commercial pressures and the involvement of the developer, substantial development delays have been experienced. The project is under construction and completion is now scheduled during 2002 well beyond the period for which the research was planned. However, the research that was undertaken included an analysis of a range of property and construction options in order to assist the project team to decide on the location and configuration of the proposed building. The research work (Aye et al, 2000) concentrated on:

- property and construction matters,
- life cycle costing and energy.

Life cycle costing
Each of the property options was costed to take into account the following life cycle costs and benefits:

- the initial property cost, i.e. the purchase price of an alternative property or the value of the existing property in the do nothing option.
- the cost of any building or renovation works (including the embodied energy in the building materials specified).
- the operating costs of the building which are classified into variable costs (energy, maintenance, cleaning) and fixed costs (insurance, rates and taxes)
- disposal (demolition) costs/recycling benefits.

In commercial feasibility studies, all future costs are discounted to reflect the time value of money and this has been undertaken for operating costs excluding energy costs. However, where non-renewable energy sources are contemplated, a current theory is that these costs should not be discounted as discounting implies replacement.

Options
Various approaches and opportunities are researched and compared with suitable benchmarks. Two benchmarks were adopted, first the true “do nothing” option of remaining in the existing property without upgrading and second the acquisition of an “ideal” site and the construction of a new building with minimal constraints to obtaining the optimum in environmental outcomes. The benchmarks represent the two extremes of the range of options.

The options examined were to:
• remain in the existing property and renovate,
• acquire a property with an existing building in the preferred location and renovate,
• acquire land in the preferred location and construct a new building.

Results
Table 1 shows the life cycle cost calculations for the options. The costs include initial property cost, building cost, energy costs, other operating costs and disposal costs. Total costs for each option are provided together with an analysis of cost per m$^2$. A guide to the value on completion assuming market recovery is also included.

The life cycle cost results show that the construction of a new building on a cleared site is only marginally more expensive per sq m than the do nothing option. The much higher energy costs per m$^2$ in the “do nothing” option offset most of the capital costs of a new building. The life cycle cost results also show that the refurbishment of an existing building is substantially higher in cost than the construction of a new building. The new buildings are more energy efficient than the existing buildings and refurbishment costs are greater than the costs of new construction.

The costs are compared with the projected market values. The costs of the refurbishment options are substantially greater than their values whilst those of the new buildings are of the same order as their values.

Life cycle energy results for each option were also calculated for operating energy only.

In broad terms, a new building would consume about twice the capital energy of a refurbishment. If these figures are taken into account, there is little to choose in life cycle energy between new and refurbished buildings. It is stressed that the energy figures were the results of broad calculations.
Table 1: Life cycle costs and values

<table>
<thead>
<tr>
<th>Option</th>
<th>Do nothing</th>
<th>Refurbish existing</th>
<th>Buy &amp; refurbish</th>
<th>Buy &amp; build</th>
<th>Buy &amp; build “ideal” site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial property cost</td>
<td>$1,600,000</td>
<td>$1,600,000</td>
<td>$1,100,000</td>
<td>$900,000</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Floor area (m²)</td>
<td>1173</td>
<td>1173</td>
<td>1350</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Building cost per m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New building</td>
<td></td>
<td></td>
<td>$1,500</td>
<td>$1,500</td>
<td>$1,500</td>
</tr>
<tr>
<td>Refurbishment</td>
<td></td>
<td>$1,700</td>
<td>$1,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building cost total</td>
<td>$0</td>
<td>$1,994,100</td>
<td>$2,160,000</td>
<td>$3,750,000</td>
<td>$3,750,000</td>
</tr>
<tr>
<td>Electricity per year</td>
<td>$7,360</td>
<td>$7,500</td>
<td>$8,000</td>
<td>$14,000</td>
<td>$12,000</td>
</tr>
<tr>
<td>Gas per year</td>
<td>$4,060</td>
<td>$1,400</td>
<td>$1,600</td>
<td>$2,500</td>
<td>$2,000</td>
</tr>
<tr>
<td>Total energy costs</td>
<td>$285,500</td>
<td>$222,500</td>
<td>$240,000</td>
<td>$412,500</td>
<td>$350,000</td>
</tr>
<tr>
<td>Other recurring costs</td>
<td>$526,500</td>
<td>$586,500</td>
<td>$675,000</td>
<td>$1,250,000</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Costs of disposal</td>
<td>$117,300</td>
<td>$117,300</td>
<td>$67,500</td>
<td>$125,000</td>
<td>$125,000</td>
</tr>
<tr>
<td>Total life cycle costs</td>
<td>$2,529,300</td>
<td>$4,250,400</td>
<td>$4,242,500</td>
<td>$6,437,500</td>
<td>$6,475,000</td>
</tr>
<tr>
<td>Costs per m²</td>
<td>$2,156</td>
<td>$3,854</td>
<td>$3,143</td>
<td>$2,575</td>
<td>$2,590</td>
</tr>
<tr>
<td>Value oer m²</td>
<td>$1,600</td>
<td>$2,400</td>
<td>$2,500</td>
<td>$2,600</td>
<td>$2,750</td>
</tr>
</tbody>
</table>

Source: Aye et al 2000

This comparison shows that the best financial life cycle alternatives are in order of preference are:
• 1. Buy and build,
• 2. Buy and refurbish,
• 3. Do nothing,
• 4. Refurbish the existing building.

It was concluded that under optimum circumstances a new building would be the preferred option, but the choice will ultimately depend upon the timely availability of a suitable property (or site).

Carbon footprinting
Each of the main three greenhouse gas sources was discussed in Aye et al 2002 (see Table 2). The carbon sequestering capacity of trees was also investigated. Calculations were supported by known data and related investigations. A carbon budget for new buildings was established in equivalent tonnes of carbon dioxide per square metre of gross floor area. This total was translated into required land areas and units of plantation trees to compensate the building greenhouse gas generation. A ratio of land area of trees to area of building can be established.

Table 2: Greenhouse gas sources in buildings

<table>
<thead>
<tr>
<th>Source: Aye et al 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg CO₂ / m²</td>
</tr>
<tr>
<td>Operational energy</td>
</tr>
<tr>
<td>Capital energy</td>
</tr>
<tr>
<td>Transport energy</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Calculations carried out in the paper showed that 69 tonnes of Carbon can be sequestered in the form of stem wood per hectare of forest and this would bind 253 tonnes CO$_2$. It follows that the estimated carbon dioxide uptake of the plantation is about 25 kg CO$_2$ / m$^2$. If a building generates about 6194 kg CO$_2$ / m$^2$, then the required ratio of planted area to built is the ratio 6194/25 or about 250/1 This indicates that for every m$^2$ built area, an area of 250 m$^2$ forest must be planted to absorb an equivalent amount of carbon. For a proposed building of say 3500 m$^2$ this means a tree plantation of approx. 87.5 ha. (~0.875 km$^2$).

**PROPOSED PROJECT**

**Scope**

The scope of the project has been described in detail by the research team (Aye et al., 2001). Much of this material was used in the ARC application. Some of the research questions to be addressed in the project (op cit pp 2-3) are:

- What is the environmental footprint, as measured by carbon emissions, of office buildings?
- What measures/indicators of environmentally sustainable development are critical to the environmental performance of office buildings?
- How much reliance can be placed on modelling systems in the design and pre-construction phases when buildings are measured post-construction?
- To what extent do tenants/occupiers of buildings impact the environmental performance of buildings in the post-construction phase?

The proposed project is to examine the differences between buildings incorporating some energy efficient measures and buildings that have no such measures. For example, two recently completed buildings at the UoM are equivalent in location, structure, materials, quality, configuration, size and use except for the following details:

- orientation,
- energy efficient heating and cooling system,
- intelligent control of light,
- high performance, double glazing,
- glazed atrium incorporating photo-voltaic modules on the north facing elevation.
- low U-values and high shading coefficients,
- sun shading,
- thermal mass on the west façade
- insulation on perimeter walls and roof, and
- rainwater collection and reuse.

The benchmark building faces east and west and has none of the above features whilst the test building is oriented to face north and south and has all of the above features.

An initial project is planned to monitor the behaviour of the two buildings after commissioning and occupation. The planned project comprised the monitoring of a series of buildings some with environmental features and some without.
Relevant occupant behaviour is also to be monitored with particular reference to the way in which the occupants relate to the energy efficient measures (or lack of them). The incorporation of the views of non-residential building occupants into environmental research has not been dealt with in Australia.

**Resources required**

The resources required are mainly for two postgraduate (doctoral) research students and an Australian Postgraduate Award (Industry) (APAI) is sought for each of the two doctoral students.

The requirement for two APAI scholarships reflects the multi-disciplinary aspects of this research project. Environmentally sustainable development has both a highly technical aspect and a philosophical and architectural aspect. It is proposed to attract one student having a mechanical engineering background to research the technical side of the project. This entails the energy analysis from the point of view of the building technology design and of the actual data collection and analysis.

The second APAI is expected to have an architecture and/or a building background. This student will be involved in the analysis of many non-technical aspects such as the locational aspects, the embodied energy in the materials and the construction techniques used, and the measurement of the levels of comfort provided by the design and management of the buildings.

The doctoral students are to concentrate on the sample of two buildings. The purpose of the RA is to substantially extend the work to a larger sample of buildings. The RA will need to have a background in environmentally sustainable development together with experience in energy modelling and extraction of data from Building Automation Systems and from record that are to be kept by a sample of the building occupants. The requirement for full time assistance is to cover the regular visits required to the subject buildings in the survey sample. A full year’s results are required to establish the effect of the climatic seasons on the energy and comfort data.

There is also a requirement for equipment to measure thermal comfort and performance of the building heating and cooling systems, eg, humidity sensors and CO₂ sensors are essential to the project.

**Expected deliverables and outcomes**

It is expected that the conclusions to be drawn from the proposed project will be that property development, building construction and life cycle asset management can play a significant part in the quest for environmentally/ecologically sustainable development. The aim of the project is to provide a guide as to suitable benchmarks for both active and passive building design solutions. If these solutions are acceptable to building occupants, they should also be acceptable to the property market in general as reflected in the activity of developers, investors and owners as well as occupiers.

The findings of the research project are to be disseminated at national and international conferences and, ultimately, by a book outlining the principles and practice of sustainable built asset management. It is also proposed to send articles to peer-reviewed international journals for publication. It is anticipated that the findings
of the research will be disseminated in a stepwise manner annually as the research progresses, for example, to:
- International Solar Energy Society 2003 World Congress, 14-19 June, Goteborg, Sweden, and

The researchers have been involved in several recent publications in the field of sustainability, for example Aye et al (2000, 2001, 2002) and Robinson (2002).

CONCLUSIONS

The conclusion to be drawn from a discussion of the environmental management issues is that property development and building construction can play a significant part in the quest for environmentally/ecologically sustainable development. Many measures are available for reducing the impact on resources, in particular natural resources such as energy, water, air and natural building materials. Contamination and pollution both internally and externally can be optimised. However continuing legislation and discussion of policy issues is required for improvement in environmental outcomes. The adoption by many countries of international standards on environmental management should lead to an improved performance by the property and construction sector.

The rapid growth of information technology provides opportunities for the management of building performance in the environmental context as well as the financial and economic context. Greater public participation in these issues will see the stakeholders take greater ownership of their activities. The stakeholders include property owners and occupants, consultants, contractors, the community, neighbours, legislators and future generations.

The new ethic is permeating across the built environment so that decisions are beginning to be considered which are environmentally effective first and cost effective second. However sight must not be lost of the commercial aspect of property management. All stakeholders must play their part in the improvement of the environment. The community cannot expect property owners to bear all of the responsibility. This may mean that building occupation becomes a higher cost activity as the costs of dealing with at least some of the environmental consequences are absorbed.

The topic is of signal importance to the property development and construction industries. The main industry partner, the Construction Industry Institute of Australia (CIIA) comprises a membership of the major private and public sector construction and development entities in the country. CIIA has been established to support research and innovation in construction. Thus the project is supported by some 20 major construction and development concerns.

In addition, two of the members of CIIA have agreed to provide additional individual support. The first is the Public Works Department of Queensland whose mission is to effectively manage the public infrastructure to the benefit of the community. This entails developing community amenity; management and provision of essential community infrastructure, facilities and services; representing the community in wider
arenas; developing a caring and supportive community; and meeting the long-term stewardship requirements of the community. The second is the Building Commission, the Victorian regulator of building whose mission, in the context of this proposal, is to create, through regulation, a safe and sustainable built environment. The Commission recognises the urgency of the situation in working toward ecological sustainability, and the fact that both government and community expectations are at a high level. It is currently assessing opportunities for the Commission to provide meaningful, effective leadership to our industry in building sustainability.

Thus this project will help in developing long-term alliances with a wide range of the major players in construction and development of the built environment.

REFERENCES


ACKNOWLEDGEMENTS

The author wishes to thank the Faculty of Architecture Building and Planning at the University of Melbourne, the Construction Industry Institute of Australia Inc., the Department of Public Works, Queensland, and the Building Commission, Victoria, for their support for this proposed project and the Australian Research Council for its past financial support for the earlier project in environmentally sustainable development.