IDENTIFYING THE OPTIMUM BALANCE ACROSS CAPITAL, LIFE-CYCLE AND ENVIRONMENTAL COSTS IN NEW BUILD CONSTRUCTION PROJECTS

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The costs associated with buildings are many and varied and reflect the impact buildings have on their owners, users, the environment in which they are set and the environment from which the resources employed in their construction and maintenance come. If the costs associated with construction projects are to be evaluated successfully, a full understanding of these costs and how they interact and influence each other is necessary. This paper introduces a research initiative, which aims to develop a methodology to identify the optimum balance across the various costs when procuring new build construction projects. Literature reviewed identifies the costs associated with buildings. Methods used to evaluate these costs, categorizing them into capital costs, life-cycle costs and environmental costs, are discussed. The paper considers the interaction of the different cost categories and the potential of a benchmark reflecting a clear understanding of the interaction between the different cost categories, which could be set as a standard to be attained in building projects.

Keywords: benchmarking costs, building costs, full building costs, optimum balance.

INTRODUCTION

The majority of people, be they individuals or companies, do not commission new buildings. Rather they purchase, lease or rent ones that have already been constructed. Consequently, those that commission buildings rarely occupy them. As they will not occupy them in the long term, it is understandable that they are concerned primarily with the cost of producing the building and the return on their investment, and are not overly interested in the costs associated with owning and occupying them long-term (Edwards 1998). However the costs associated with producing the buildings are only the tip of the iceberg. The client of the construction process will have to pay for the site, the materials and workmanship and the design amongst others things, but it is those that use and occupy the building in the longer term who will have to pay for the buildings maintenance, lighting, heating etc. Buildings also impose costs on the community at large, be it from the pollution caused by concrete production or the knock-on traffic implications due to the location of a major building.

If the all the effects of a building are to be considered, they must first be understood. There currently exists a good understanding of capital costs, these are considered on most projects, as they are the costs experienced by the client of the building. There is theoretical understanding of life-cycle costs (use and occupancy costs) which is applied to some projects. However from the literature reviewed, there appears to be

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little consensus as to what the costs imposed by a building on the wider society are. Defining and understanding all of the costs caused by buildings will be part of this research project. Once understood individually, they and their interaction with each other, needs to be understood collectively. If the overall cost of a building it to be optimized then the correct balance across all of the individual costs needs to be struck.

Currently there is no technical reason why buildings could not be designed to reduce their impacts in terms of long-term costs and costs to the environment and cost to the wider community. The material and technology exists (Mustow 2003), as does the design knowledge (van der Dobbelsteen *et al.* 2003, Roaf 2004).

All design decisions should be taken with a full understanding of the associated costs. In the end the design process should achieve the best balance across all the costs associated with the building. This achievement of this optimum balance could be set as a design brief criteria or as a benchmark against which to evaluate tenders. The optimum balance of the different costs types could used as the motivation to ensure that designs consider all the impacts and costs associated with a building.

BUILDING COSTS

Buildings costs are often multi facetted and complex. In order to be evaluated fully they need to be understood fully. Costs generally can be defined as

- an amount given as payment, or
- an expenditure of time or labour, or
- a loss suffered in the achievement of something (Pollard 1994).

Buildings are generally very costly by any of the above definitions of cost. In monetary terms the client pays the contractor a significant amount. Construction also consumes significant amounts of time and labour, as well as materials. In terms of costs, often one willingly volunteers to suffer the loss of one thing for the achievement of something else desired, but other times the loss is suffered by a third party without that third party having any choice. The losses suffered as a consequence of the construction of a building are felt by many (Gilchrist and Allouche 2005).

The cost associated with a buildings construction represent only a small proportion of the overall cost incurred throughout the life-span of the building. The ratio of 1:5:200 representing the relative expenditure on construction costs, maintenance or facilities management costs and operational costs was calculated by Evans *et al.* (1998) although Ive (2006) argues that these proportions are exaggerated and should be in the region of 1:5:15. Whichever is correct neither account for all the costs as neither account for the impact a project has on the environment or on the wider society. In keeping with the scope of the research, it has been decided to categorize all the costs into the following three categories: capital cost, life-cycle costs and environmental costs.

Capital costs are the costs to the construction client and include the construction cost together with associated legal and design fees, land purchase and site preparation expenses, VAT and financing costs (Ferry *et al.* 1999, El-Haram *et al.* 2002).

The life-cycle costs are the costs to the owners and occupiers of the completed building. They include maintenance / facilities management costs and operational costs referred to previously and the replacement and disposal costs of the building and parts thereof (Ferry *et al.* 1999, Wordsworth 2001, El-Haram *et al.* 2002). These are not always considered when projects are commissioned, perhaps due to the short-term association that the client has with the building (Edwards 1998), or also perhaps due to the lack of reliable and consistent data (El-Haram and Horner 1998). However, as new legislation such as the Building (Amendment) Regulations (Northern Ireland) 2006 (The Department of Finance and Personnel 2006) and the Directive on Energy Performance of Buildings (EU 2003) are enacted, life-cycle costs will need to be considered as a matter of course.

Agreement as to what constitute the environmental costs is less established. Those that have defined these costs identified amongst others some or all of the following items: the effects on local communities of sourcing materials (mining, pollution), the use of non-renewable materials (cement, metals, rock), the use of green field sites, the effect on the biosphere, air and water pollution, the effect on the occupants (sick building syndrome, indoor air quality,) (EU 2004; BRE 2005). Others argue for more, such as ethical issues (Mustow 2004), cultural impact (Cooper 1999) and respect for all people and communities (Myers 2004). Again, with the introduction of legislation and regulations identified above, these impacts will have to be considered and measured.

Given that buildings are associated with such significant levels of complex expenses ensuring the best value, or the most economically advantageous building, is difficult. Not least because the question best value for whom would need to be answered. Should best value be measured in terms of the capital cost to the client commissioning the building, or in terms of the life-cycle costs to those who will use the building during its life span, or should it be measured in terms of the environmental impact of the building that affects the society at large?

MEASURING COSTS

The answers to the question posed above are outside the scope of this paper and this research project. This research project assumes that balancing the costs across each of the three cost categories identified previously will give the best value. In order to establish what this balance will be, it will first be necessary to measure the costs associated with each cost category individually for a range of projects.

Capital costs and in particular the construction costs are measured on a building project on an ongoing basis throughout the design and construction stages of a project. Preliminary estimates, cost plan, tender evaluations, cost reports, interim accounts and final accounts are all carried out on the majority of buildings projects (Seeley 1997).

Life-cycle cost assessment are economic assessment which consider all the significant costs of ownership over the economic life of an product (Dell'Isola 1982). It considers the effect of time on value and calculates future events in present values (Singh and Tiong 2005). Life-cycle cost assessments have been applied to many projects, particularly those where the tender includes an element of design such as Design and Build or Public Private Partnerships and since 2001 seventy per cent of government departments in the UK must use them (El-Haram *et al.* 2002).

Many assessment tools to measure the environmental costs associated with buildings have been developed in recent years. The BRE's BREEAM, and the US system LEED (Sinou and Kyvelou 2006) are two such and there are many more. In 2004 a European Union thematic network (CRISP 2004) looking at sustainability indicators relating to construction identified 40 different tools in use across the European Union. It is probably safe to assume this number has grown since.

In the measurement of sustainability and environmental costs generally, there are two schools of thought. The first advocates putting a monetary value on all the environmental cost factors, the second opposed this. Bartelmus (1999) reflecting on the merits of both approaches summarized them as follows:

Environmental Economics
The view of environmental economists is to put a monetary value on environmental resources and then to treat them as a commodity: how much will people pay for them. Environmental economists want economic activity preserved by maintaining produced and natural capital.

Environmentalism:
The view of environmentalism is that the environment is like heritage and cannot be expressed in monetary terms. Indicators are needed, ideally linked to limits / thresholds or similar. Environmentalists want human well-being preserved by providing territory, natural assets and a suitable standard of living.

The alternative approaches have also be labelled as "weak" and "strong" sustainability (Pearce and Barbier 2004, Williams and Millington 2004 and Getzner 1999). Weak sustainability broadly corresponds with environmental economics and believes human kind does not have to change its behaviour, technological developments will provide sustainability, although this technology will cost. Strong sustainability believes the opposite, that human behaviour must change and technology has no contribution to make. This broadly corresponds with environmentalism.

The trend in the construction industry has been to develop assessment tools that follow the "strong" view, as the majority of tools developed do not attempt to place a monetary measure on the factors they evaluate, rather they place a rating on it. The tools typically consist of many individual indicators reflecting the range of potential impacts a building project could have on the environment. Collectively these impacts reflect how sustainable the project is in its design and construction and use throughout its life span. These indicators, with each one linked to a benchmark or standard, measure the performance of the buildings. The rating awarded to the building is decided by considering the performance of the building across all indicators.

For this research project, each of the three cost categories will be measured using existing industry best practice techniques, for a number of building projects. There is a risk of overlap occurring resulting in some factor being measured twice in two different categories. When considering the best methods to measure each category, this will be considered carefully.

If the best building for all (construction clients, future owners and occupiers and society generally) is to be produced, consideration should be given to all aspects of cost at the design stage and an attempt should be made to achieve a fair balance, the optimum balance, between these costs. The aim of this research project therefore is to develop a methodology to identify that optimum balance across these cost categories of environmental costs, capital costs and life-cycle costs when procuring new build construction projects.

RESEARCH METHODOLOGIES

A methodology has been developed to achieve the aim stated above. The methodology comprises of three stages, which are shown in the schematic below (Figure 1). These are the Literature Review, the Empirical Research and the Test and Disseminate stages.

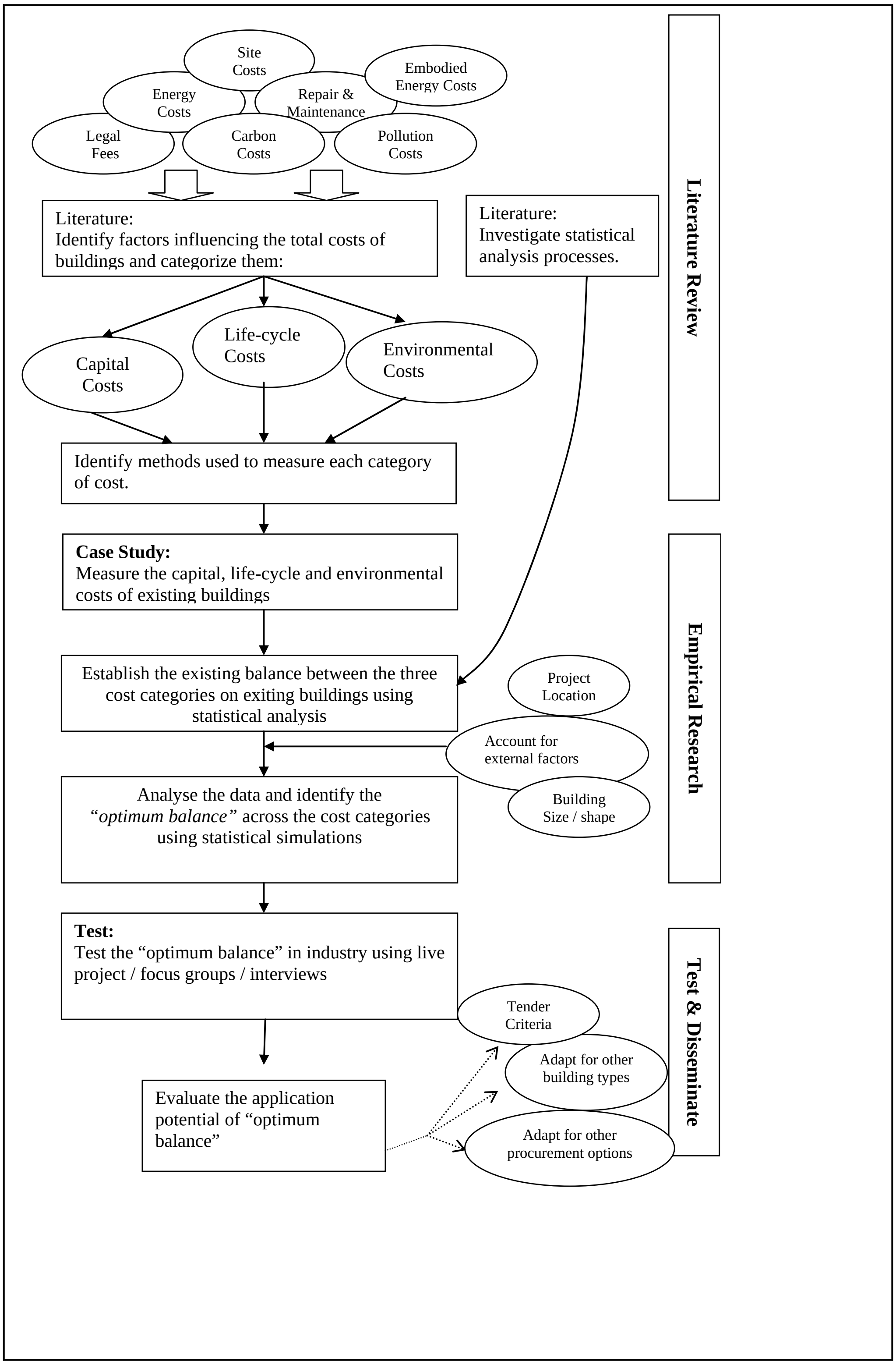

Figure 1: Research Methodology

In the Literature Review stage all cost factors a building imposes on its owners, users and society in general such as pollution costs, sites costs, construction costs etc will be identified and then categorized under the headings of capital costs, life-cycle costs and environmental costs. Methods of measuring these individual costs will be investigated as will statistical analysis processes which will be needed later.

In the Empirical Research stage, data pertaining to existing buildings will be gathered. This data will be used to calculate the capital, life-cycle and environmental costs as identified in the earlier stage for each existing buildings. To ensure the data is comparable, the measurement of it will be conducted using consistent methodologies identified in the Literature Review stage. A statistical analysis of this data will then be conducted to establish the existing correlation across the three cost categories. With the existing correlation established the data would be interrogated to allow for external factors such as inflation and building shape and location. Then, statistical simulations will be used to identify the "*optimum balance*" across the three cost categories.

In the Test and Disseminate stage of the research project, the "*optimum balance*" identified will be tested, as will its suitability as a benchmark set as part of a design brief or tender evaluation criteria. The aims of the test will be to establish

- whether the benchmark could be applied to real projects
- whether the inclusion of the benchmark as a target for tenders would influence the tender submission, or would any effect be coincidental
- whether the same effect could have been achieved by simply requesting designers to consider life-cycle and environmental issues, without presenting a benchmark
- whether practitioners would have difficulties understanding / achieving the objective

Ideally this test will take the form applying it to a live project. Alternatively it may be possible to examine its suitability through focus group discussions with practicing professionals from the construction industry. A third option would be to investigate its suitability through interviews with industry practitioners. Depending on the outcome of the test the potential applications for the research will be explored further.

APPLICATION OF THE OUTCOME

The exact presentation format of the "optimum balance" is yet to be decided. Whether the benchmark is to be applied to a tender return (as in design and build, or similar) or whether it is to be applied to a design brief, may influence the nature of the format. Currently, there are four alternative formats under consideration

Alternative One

Table 1: Optimum Balance as Target Cost per Gross Floor Area

Cost Category	**Budget Targets**
Capital Costs	£a-b / m^2 gfa
Life-Cycle Costs	£c-d / m^2 gfa / annum averaged over 10 years
Environmental Costs	£e-f / m^2 gfa

In this alternative (see Table One) the optimum balance would be converted to budget targets. The capital costs would be expressed in £/m^2, the life-cycle costs in £/m^2 averaged over a certain length of time and the environmental rating would be converted to £/m^2 also. The designers or contractors could be given these budget targets as part of a brief. Alternatively, submitted schemes, either as part of a design competition or as part of a tender could be compared to the optimum balance as expressed in target costs. The target cost would reflect the identified optimum balance across the building costs.

Alternative Two

Table 2: Optimum Balance as Target Ratio of Cost per Gross Floor Area

Cost Category	Target Costs Ratios
Capital Costs	£a / m^2 gfa
Life-Cycle Costs	£2a / m^2 gfa over 10 years
Environmental Costs	£6a / m^2 gfa

In this alternative (see Table Two) the optimum balance would be converted into ratios. The capital costs would be expressed in £/m^2, the life-cycle costs and the environmental costs would be multiples of that cost. Again, the designers or contractors could be given these targets ratios as part of a brief. Alternatively, submitted schemes, either as part of a design competition or as part of a tender could be compared to the optimum balance as expressed in target ratios of cost. The target ratios would reflect the identified optimum balance across all the building costs.

Alternative Three

Table 3: Optimum Balance as Weighting

Tender	BREEAM Rating	LCC Range	Tender Sum £	Tender Ranking	Adjust by	Adjusted Tender Sum	Adjusted Tender Raking
1	Pass	£a-b	1 500 000	1	+20%	1 800 000	4
2	Good	£c-d	1 700 000	2	0	1 700 000	3
3	V good	£e-f	1 800 000	3	-20%	1 440 000	1
4	Excellent	£c-d	2 000 000	4	-20%	1 600 000	2
5	Excellent	£a-b	2 200 000	5	-10%	1 980 000	5

Notes on Table Three:

Hypothetical Adjustment for environmental rating based on BREEAM assessment:

Pass (+10%), good (0%), very good (-10%), excellent (-20%)

Hypothetical Adjustment for life-cycle cost assessment:

£a-b/m^2 /10yrs (+10%), £c-d/m^2 /10yrs (0%), £e-f/m^2 /10yrs (-10%)

In this alternative (see Table Three) the optimum balance would be expressed in weightings or adjustments to the tender sum. It would be suitable for projects that involve contractor design, although it could be adapted for other situations. The tenders received would be analysed in terms of construction costs, life-cycle costs and environmental costs. This tender sum would be adjusted higher or lower on a percentage basis depending on the life-cycle costs and the environmental rating, as calculated using the BREEAM system in the example set out above. The tender would be awarded on the basis of the adjusted tender sum. This system would motivate the contractor to design will all costs in mind, not just the construction costs.

Alternative Four

Table 4: Optimum Balance as Relative Significance Applied to each Tender Criteria

Tender	**Criteria Score (out of 10, 1 being low)**				**Criteria Value**				**Total**
	A	**B**	**C**	**D**	**A x 0.2**	**B x 0.1**	**C x 0.3**	**D x 0.4**	
1	5	5	5	5	1.0	0.5	1.5	2.0	5.0
2	5	2	8	5	1.0	0.2	2.4	2.0	5.6
3	3	7	3	7	0.6	0.7	0.9	2.8	5.0
4	6	1	6	9	1.2	0.1	1.8	3.6	6.7

Notes on Table Four:

Hypothetical Criteria Significance

A. Design solution, space, fit-out etc. 20%

B. Capital costs 10%

C. Life cycle costs 30%

D. Environmental costs 40%

Example Tender profiles:

P1. Average everything

P2. High capital cost, low LCC costs, average others

P3. Poor design, good capital costs, poor LCC, good environmental costs

P4. Excellent environmental costs, high capital cost, moderately good LCC and design

RESULT

From a potential maximum total of 10, Proposal 4 is favourite

In this alternative (see Table Four) the optimum balance would be expressed as a relative significance across the multiple criteria to be considered in evaluating a tender proposal. As with the previous alternative it would be suitable for projects that involve contractor design, although it could be adapted for other situations. The tenders received would be analysed in terms of design as well as construction costs, life-cycle costs and environmental costs. Each of the criteria would be scored out of a possible maximum of ten marks. These scores would then be adapted reflecting their relative significance in achieving the optimum balance. The resultant aggregate of the scores would form the basis of the tender award. Again, this system would motivate the contractor to design will all costs in mind, not just the construction costs.

Although the research data and therefore the optimum balance identified will only be directly comparable to projects similar to those used in collecting the data in the empirical research stage, it is hoped it will be easily adaptable to other project types and other procurement practices. If comparing refurbishing a building with demolishing and rebuilding it, the relative significance given to waste and water pollution as compared to the reduction of green house gas emissions will have an importance impact on the result (Dong *et al.* 2005).

CONCLUSION

The overall costs associated with a building are multi facetted and are experienced by many different people. However they can be categorized under the heading of capital cost, life-cycle costs and environmental costs (which included costs experienced by society). Every design decision should consider all the associated costs however many focus mainly on the capital costs. Legislative and regulatory changes will go some way towards changing this practice.

If all costs are to be considered and balanced effectively, the interaction between them needs to be understood. The aim of the research is to establish this optimum balance across costs. To do this, first it will be necessary to understand all the costs, measure them in existing projects and establish how they interact in existing projects. This information will then be analysed to identify the optimum interaction or the optimum balance across the costs. Once identified it will need to be converted to a benchmark or similar which can be tested in the field.

It is envisaged that the primary outcome of this work will be a benchmark identifying the optimum balance between these three costs, which can then be specified in the construction industry. It could be specified as part of the design brief criteria in a traditionally procured project where the designers team would have to design to it. Alternatively it could be used in design and build style procurement as part of a tender evaluation exercise where the tender is analysed using multiple decision making criteria. Although this benchmark will be developed on the basis of data from a single type of project and a single procurement option, it is envisaged that the results will be readily adaptable to other project types and other procurement options. In all cases, the optimum balance could be used as the motivation to ensure that designs consider and balance all the impacts and costs associated with a building.

REFERENCES

Bartelmus, P, (1999) Green accounting for a sustainable economy. Policy use and analysis of environmental accounts in the Philippines. *Ecological Economics,* **29,** 155-170.

BRE, (2005) *EcoHomes 2005: The Environmental rating for homes. The Guidance: 2005 / Issue 1.1*. Garston: Building Research Establishment Ltd.

Cooper, I (1999) Which focus for building assessment methods: environmental performance or sustainability? *Building Research and Information,* **27**(4/5), 321-331. .

CRISP, (2004) *A European Thematic Network on Construction and City Related Sustainability Indicators, Final Report.* Brussels: European Union.

Dell'Isola, A J (1982) *Value engineering in the construction industry* 3ed. USA:Van Nostrand Reinhold.

DEPARTMENT OF FINANCE AND PERSONNEL, (2006). *The Building (Amendment) Regulations (Northern Ireland) 2000.* Available at www.opsi.gov.uk/sr/sr2006/20060355.htm, accessed 27th April 2007.

Dong, B, Kennedy, K and Pressnail, K (2005) Comparing life cycle implications of building retrofit and replacement options. *Canadian Journal of Civil Engineering* **32** 1052-1063.

Edwards, B, (ed) (1998) *Green Buildings Pay*. London: E & F N Spon.

El-Haram, M and Horner, M (1998) Factors affecting life cycle cost in the construction industry, *Proceedings of the 8th International Logistics Symposium,* Exeter.

El-Haram, M, Marenjak, S and Horner, M (2002) Development of a generic framework for collecting whole life cost data for the building industry. *Journal of Quality in Maintenance Engineering,* **8**(2), 144-151.

European Union, (2003) *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.* Brussels: European Union.

European Union, (2004) *Towards a thematic strategy on the urban environment, EU Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions.* Brussels: European Union.

Evans, R, Haryott, R, Haste, N and Jones, A (1998) *The Long Term Costs of Owning and Using Buildings* Royal Academy of Engineering: London.

Ferry, D, Brandon, P, and Ferry, J (1999) *Cost Planning of Buildings* 7ed. Oxford: Blackwell Science.

Getzner, M (1999) Weak and strong sustainability indicators and regional environmental resources. *Environmental Management and Health,* **10**(3), 170-176.

Gilchrist, A and Allouche, E A (2005) Quantification of social costs associated with construction projects: state-of-the-art review. *Tunnelling and Underground Space Technology,* **20**(1), 89-104.

Ive, G (2005) Re-examining the costs and value ratios of owning and occupying buildings. *Building Research &Information,* **34**(3), 230-245.

Mustow, S (2004) Procurement of Ethical Building and Construction Products *In: COBRA 2004,* 7-8 Sept 2004, Leeds: RICS Foundation.

Myers, D (2004) *Construction Economics: A New Approach* London: Spon Press.

Pearce, D and Barbier, E (2000) *Blueprint for a Sustainable Economy.* London: Earthscan Publications Ltd.

Pollard, E (ed) (1994) *The Oxford Paperback Dictionary.* Oxford: Oxford University Press.

Roaf, S with Horsley, A and Gupta, R (2004) *Closing the Loop, Benchmarks for Sustainable Buildings* London: RIBA Enterprises.

Seeley, I H (1997) *Quantity Surveying Practice,* London: Macmillan.

Singh, D and Tiong, R L K (2005) Development of life cycle costing framework for highway bridges in Myanmar. *International Journal of Project Management,* **23**, 37-44.

Sinou, M and Kyvelou, S (2006). *Present and future of building performance assessment tools,* Management of Environmental Quality: An International Journal, **17**(5), 570-586.

van der Dobbelsteen, A A J F, Arets, M J P and van der Linden, A C (2003) Smart Sustainable Office Design: Effective Technological solutions, based on typology and case studies. *In*: Yang, J, Brandon, P S and Sidwell, A C (Eds.), *The CIB 2003 International Conference on Smart and Sustainable Built Environment,* 19-21 November 2003, Brisbane, Australia.

Williams, C C and Millington, A C. (2004) The diverse and contested meaning of sustainable development. *The Geographical Journal,* **170**(2), 99-104.

Wordsworth, P (2001) *Lee's Building Maintenance Management* 4ed. Blackwell Science: Oxford.