Computer Aided Design Appraisal

A Modest Experiment

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The paper starts with a re-iteration of the concept of appraisal of digital prototypes during the early phases of the architectural design activity and with a summary of research and development from the early seventies to the current time; the use of appraisal by progressive practices is described in the context of the company Integrated Environmental Systems.
The paper then focuses as an experiment which set out to determine how the information delivered by the computer based appraisal of virtual prototypes is ordered and used by professionals in the evaluation of design alternatives. The information provided to the professionals is detailed and their self-assessment of their management and utilsation of the data is reported, together with their critique of the experience.
Conclusions are drawn and future research directions proposed.

Keywords: *Appraisal, evaluation, design alternatives, performance, experiment.*

Background

Although the term „virtual prototype" is relatively recent, the concept of constructing, digitally, a model of a proposed building within the computer goes back to the early seventies (Maver, 1971). It was argued then that, whereas the design of most artifacts (toothbrushes, furniture, cars, etc) involved the progressive refinement of a physical prototype in advance of a large production run, this paradigm was inappropriate to the design of large capital cost items such as buildings. What was appropriate, it was argued, was the iterative refinement of a virtual (i.e. a digital) prototype. The idea of simulating the behaviour of virtual prototypes and recording and comparing their profile of cost and performance has been a continuing theme in parts of the CAAD community. Signal contributions to the development of appropriate and increasingly sophisticated software tools for prototype appraisal have been made by Milne (1990), Mahdavi (1996), Pohl (1994), Papamichael (1996), Augenbroe (1995) and Clarke (1991).
Clarke's work at the University of Strathclyde led to two initiatives aimed at making the emerging and increasingly complex simulation software accessible to architectural and engineering practioners. One was the creation of a government supported Energy Design Advisory Service; over the period

1981-1993 the advice given to some 1500 practitioners yielded audited annual saving in energy consumption of around 30 MEURO. The second initiative was the spin-out of a commercial company in 1980, currently known as Integrated Environmental Solutions (IES); IES (www.iesve.com) has built up an international clientele by providing simulation services on a wide range of prestigious architectural projects.

The validity and value of the sophisticated software tools currently available is generally accepted. The questions which remain, and on which this paper focuses, relate to the complex designerly responses which humans make to the opportunities afforded by the emerging technologies; i.e. why clients/practitioners use them, how they use them, when, in the course of the design activity, they are used and what are the real and perceived outcomes.

Two earlier studies are worth noting. Leclercq (1991) reported to the eCAADe annual conference on the use of advanced software tools for training architectural students in efficient energy management. Together with the Department of Educational Technology at the University of Liege, he studied the efficacy of the use of energy simulation software on the users learning and behaviour. Petric (1993) reported at eCAADe on the learning experiences of one 3rd year architectural student using software known as GOAL (General Outline Appraisal of Layouts) to assist in the design of a Primary School. The paper is a clear account of the way in which the student deployed the cost/performance information yielded by GOAL to refine her initial concept, through 9 variants to a final scheme which was demonstrably and significantly superior on all objective criteria (Figure 1).

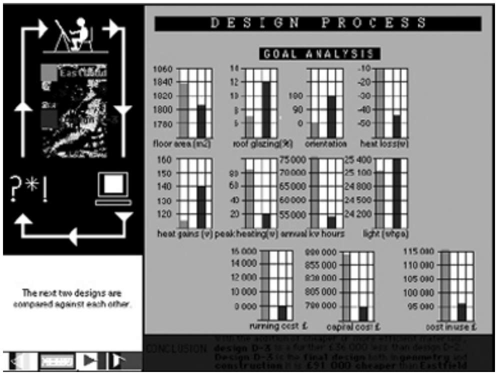

Figure 1

Current Experiment

The work reported by Leclercq and by Petric had two limitations which the experiment reported here seeks to address:

i) both cases involved architectural students who had no knowledge of actual practice in the real world or of the inherent priorities of real client bodies.
ii) in both cases, the students had to climb a difficult learning curve in the deployment of the software tools; the degree to which they managed would surely impact on the design outcomes.

The authors looked for a situation involving practitioners rather than students and sought to eliminate the effects of skill in operating the tools. The opportunity arose as a result of collaboration between the University and IES to provide a module entitled „ICT as an Agent of Change“ in an MSc Course in Innovative Construction, intended to bring a small number of ambitious mid-career professionals from a variety of disciplinary backgrounds up to speed in ICT. The delegates (four in number) were exposed to the idea of computer-based virtual prototyping and given an assignment, over a six week period, back in their place of employment, focused on computer aided design appraisal.

In preparation for the assignment, IES took a real design brief from their current portfolio of work and simulated, using the software package DEFT, the cost/performance of 6 design variants: 2 geometries, 3 levels of glazing, 2 options of glazing technology and 2 different orientations. Each delegate was provided with a computer graphic, solarly shadowed (Figure 2) and three spreadsheets representing the outcomes of the virtual prototyping, viz:

i) the results of the appraisal in real terms, viz; floor area, volume, occupancy, capital cost, peak heating, peak cooling, annual heating, annual cooling, annual lighting, running cost, primary energy demand; carbon dioxide (C02), net present value, total C02 emission (KgC) and daylight comparison (lux) (Table 1) .
ii) the percentage difference between the notional „base case“ and 5 subsequent design variants.
iii) the same spreadsheet, but with the opportunity for the delegates to make a determination of whether or not a higher or lower score was better or worse and, indeed if a weighting of importance could be applied to determine an numerical outcome (Table 2).

Delegates were required to:

i) effect an analysis of the data provided, from their own perspective, and form a view as to which of the 6 design options was „best“.
ii) propose which new design options ought to be the subject of the next round of simulations, and why?
iii) provide a 500 word account of their experience of the assignment and its relevance to their role in the building industry.

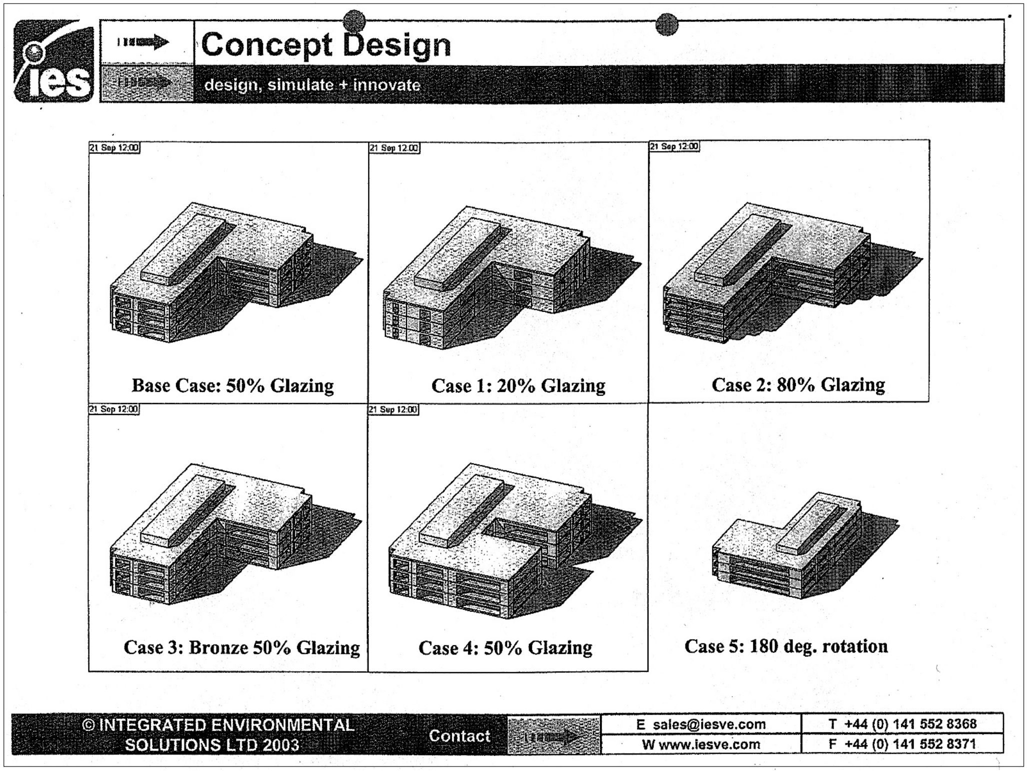

Figure 2

Experiment Outcomes

Three of the four delegates submitted the assignment within the time allotted and to a high standard. As a result of a query from one delegate during the period of the assignment, it was agreed that the client should be assumed to be a commercial company that is both owner and occupier; interestingly, this is a consideration which would have had no significance to undergraduate students!

The submissions in all three cases contained a wealth of interesting information, much of which is still being analysed. The general approach to the assignment was broadly similar in all three cases although there were some interesting variations. The authors observations

i) two of the three delegates, acting perhaps on a prompt from the tutors, chose to compare each of the six design variants not against the nominal „base case“, but against the average of all six (see, for example, Figure 3).

ii) one of the delegates carried out the analysis with different weightings between the cost/perfor-

Summary of results for all six options					
		Base Case	Option 1	Option 2	Option 3
1	Floor Area	4,362.1	4,362.1	4,362.1	4,362.1
2	Total Volume	17,891.9	17,891.9	17,891.9	17,891.9
3	Net Lettable Area	4,257.1	4,257.1	4,257.1	4,257.1
4	Max. Occupancy	354	354	354	354
5	Capital Cost	4,888,718	4,754,366	4,978,286	4,944,698
6	Peak Heating	310.0	296.1	319.3	312.8
7	Peak Cooling	325.0	248.4	374.2	248.4
8	Annual Heating	48,238.0	30,370.0	52,340.0	55,222.0
9	Annual Cooling	293,127.0	240,170.0	321,937.0	203,412.0
10	Annual Lighting	233,527.0	226,577.0	226,577.0	226,577.0
11	Running Cost	16,431	14,989	17,337	15,123
12	Primary Energy Demand	1,508,996	1,357,575	1,542,144	1,325,507
13	Carbon Dioxide (CO2)	400	358	409	352
14	Net Present Value	521,031	571,156	602,650	525,689
15	Total Carbon Emissions (KgC)	80,358.0	72,841.0	82,691.0	76,351.0
16	Daylight comparison (Lux)	319	255	346	105
	* 50% double glazing				
	* 20% double glazing				
	* 80% double glazing				
	* As Base Case with bronze antisun glazing				
	* larger building u shaped				
	* As Base Case with 180 Deg. rotation				

Table 1
Cost and performance characteristics of 6 design variants as predicted by the DEFT software.

Figure 3

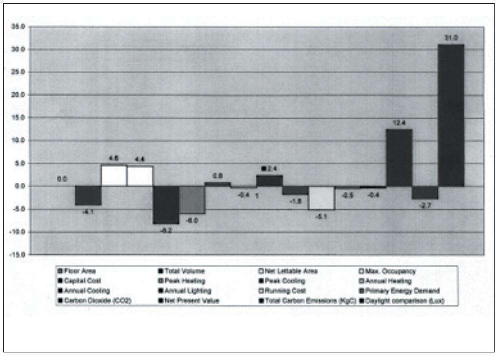

Table 2

Scenario Analysis								
		Higher or Lower	Weighting Factor	Option 1	Option 2	Option 3	Option 4	Option 5
1	Floor Area	1	1	0.0	0.0	0.0	0.0	0.0
2	Total Volume	1	1	0.0	0.0	0.0	0.0	0.0
3	Net Lettable Area	1	1	0.0	0.0	0.0	0.0	0.0
4	Max. Occupancy	1	1	0.0	0.0	0.0	0.0	0.0
5	Capital Cost	1	1	0.0	0.0	0.0	0.0	0.0
6	Peak Heating	1	1	0.0	0.0	0.0	0.0	0.0
7	Peak Cooling	1	1	0.0	0.0	0.0	0.0	0.0
8	Annual Heating	1	1	0.0	0.0	0.0	0.0	0.0
9	Annual Cooling	1	1	0.0	0.0	0.0	0.0	0.0
10	Annual Lighting	1	1	0.0	0.0	0.0	0.0	0.0
11	Running Cost	1	1	0.0	0.0	0.0	0.0	0.0
12	Primary Energy Demand	1	1	0.0	0.0	0.0	0.0	0.0
13	Carbon Dioxide (CO2)	1	1	0.0	0.0	0.0	0.0	0.0
14	Net Present Value	1	1	0.0	0.0	0.0	0.0	0.0
15	Total Carbon Emissions (KgC)	1	1	0.0	0.0	0.0	0.0	0.0
16	Daylight comparison (Lux)	1	1	0.0	0.0	0.0	0.0	0.0
	Total			0.0	0.0	0.0	0.0	0.0
	Any -ve value means the value is ‘worse’ than the base case							
	* 1 = better to be higher than base case							
	* -1 = better to be lower than base case							
	* change weighting factor as appropriate							

mance variables under three different assumptions, that of „developer“, „lease-holder“ and „owner/occupier“; for the owner/occupier, he decided Option 4 was best and for the other two, Option 1 was best.

iii) all three carried out „sensitivity“ studies to investigate the impact on the „best“ decision of changes to the weightings between the variables.

iv) all three, in their commentary, recognised the complexity inherent in a multi-variate parametric study and offered, to some limited degree, search stratagems: i.e. ways of getting, through further simulation, how to get from „here“ to „there“,

v) All three agreed that for a commercial owner/occupier, Option 1 represented the best case for further investigation.

vi) All three acknowledged that increased information, although difficult to handle, improved the prospects for design decisions which benefited the end user; these benefits were variously identified as: design control; cost control, design coordination; reduced energy consumption; increased plant efficiency; reduced life-cycle costs; reduced emissions; improved comfort; elimination of guesswork; power to convince; visualisation; contribution to conceptual stages in design; integration.

vii) none of the three delegates identified, explicitly, the importance of the approach to the future auditing of the design decision-making process.

Conclusions

The authors claim only that this modest exercise offers a further tiny peephole into the immensely complex world of architectural design decision making; more positively, it is claimed, the outcomes reinforce most of the issues identified as critical in the early publications in the field, to our better understanding and practice of architectural design. These include:

i) recognition, by involving participants from industry as opposed to students, that the design decision-making process is not only multivariate but multiperson (and multi-organisational): ultimately the choice between options is value-led and subjective.

ii) importantly, subject value judgement is aided rather than impeded, by objective appraisal and comparative analysis; clients, users and the general public need to know the trade off between, for example increased cost and aesthetic quality.

iii) although it is not explicitly stated in the assignment reports, the authors have the idea that the delegates gained generalised insights into the cause effects of design decisions on cost/performance outcomes; if so, this will carry forward to their future design activities .Early publications in the field hoped not just for a „peephole“ but for a transformation in our understanding of design from a „black box“ to a „glass box“; clearly, we are a long way from this goal which, perhaps, can only approach asymptotically. Nonetheless, the simple experiment reported in this paper offers, perhaps, one way forward.

Early publications in the field hoped not just for a „peephole“ into the design scenario; the ambitious idea was that design appraisal had the potential to transform the „black box’ of willful and arbitrary design decision-making by an arrogant and elitist profession into a „glass box“ within which the causal effects of how design decisions would be revealed to ALL those who are affected by them, and who would be empowered to participate , from an informed point of view, in the creation of an environment which is fitter for purpose, more sustainable and, the authors believe, no less architecturally outstanding. This paper is a modest contribution to the enduring idea.

Acknowledgements

Thanks to all those in the CAAD community who keep the concept alive and more specifically to

Dr Don McLean of IES. Special thanks to the MSc Delegates, Steve Druett, John McBeth, John McWilliams and David Mitchell-Hill who did much more than simply satisfy the minimal requirements of their assignment; their ready acceptance of the concept and their commitment to demonstrating that they could make it work, within the constraints of juggling work with learning,, has been an inspiration to the authors.

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