TRANSFERRING SIMULATION FROM SPECIALISTS INTO DESIGN PRACTICE

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ABSTRACT

Building simulation tools (energy, lighting, plant simulation, CFD, *etc*) have long been the preserve of a few specialist consultancies rather than being used where they can have the greatest impact - by construction design practices. This has resulted in additional costs for designers (time and financial) in terms of buying in specialist services. In addition, the designer is not able to fully explore the design potential: being restricted by what the specialist reports back.

There are myriad well-recognised reasons for this situation: the perceived difficulty of using simulation tools; the cost (licences, suitably trained staff, hardware); liability issues; and so on. Also, the construction industry is a traditionally a poor investor in research and development, preferring to operate core business activities on proven ground.

Despite this, IBPSA Scotland has, over the last three years, succeeded in transferring simulation capabilities into local businesses, primarily in the building services sector. This has resulted in enhanced design quality, and (more importantly) increased business for participating companies. This begs the question: why, despite these barriers, have these companies succeeded?

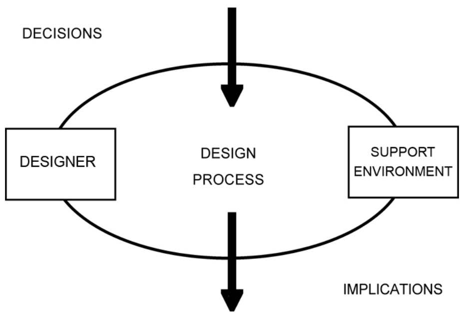
This paper explores the technology transfer mechanisms and details which have been successful and which have not. In both cases, reasons for success and failure are identified and analysed. The paper goes on to describe how this knowledge has been used to guide the future plans of IBPSA Scotland, including widening appeal within the design team, and targeting architects in particular through a new Scottish Executive initiative.

INTRODUCTION

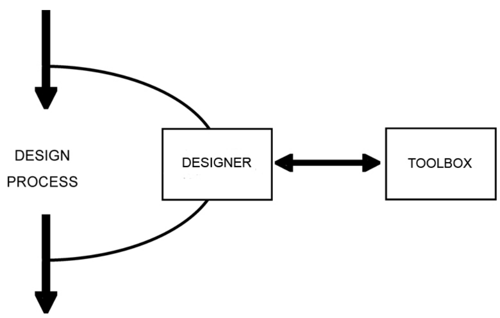
Over the past 15 years simulation tools and skills have moved from the academic domain into specialists practices and are now in use by general consulting engineers. Organisations such as the Energy Design Advice Service [ETSU] and the Scottish Energy Systems Group [SESG] have helped to equip the professions with the necessary skills to allow them to apply simulation tools routinely in practice.

These projects tackled the perceived barriers to the uptake of simulation: steep learning curve, poor ease of use, fear of user error, discontinuity between program capabilities and the scale and complexity of real buildings, demanding resource requirement, credibility of predictions, need for specialist computing equipment and, most importantly, the lack of a supportive network [Howrie].

Initially the EDAS approach to providing simulation-based advice relied on the services of modelling specialists who remained detached from the design process (Figure 1(a)). Such an approach gives rise to a delay between the delivery of the simulation results and the evolution of the design hypothesis. The SESG was then founded on the belief that the industry was then ready to commence the process of adopting a computational approach to energy systems design (Figure 1(b)) whereby modelling tools are fully integrated within the design process.



(a) EDAS approach



(b) SESG approach

Figure 1: Approaches to simulation use.

Current legislative changes in Europe, notably the Energy Performance in Buildings Directive [EU], will for the first time require a computational approach to regulation compliance. Therefore, this paper aims to detail how companies who use simulation have managed the process.

THE SESG

The SESG was founded on the basis that computer modelling tools had reached a level of maturity that enabled them to be readily deployed in practice. Prior to this project, EDAS had enabled engineers to gain access to modelling specialists on a consultancy basis. While EDAS was highly successful in introducing low energy building design solutions, the approach being adopted had several shortcomings: although subsidised, the use of consultants was an extra cost; design times could be increased while waiting for reports; and the design team was not able to freely explore options as the consultant directed the process. SESG was established to address these shortcomings.

SESG is operated as an industry club, with the goal of demonstrating to its members that integrated building performance modelling provides cheaper, quicker and better design solutions than the traditional methods it seeks to replace. This demonstration is achieved via a repeating monthly cycle of events as follows.

- A seminar on a topical issue such as climate change, renewable energy, air pollution, energy labelling or pending legislation changes. The aim is to address the range of issues that impact on sustainable development and point out the role that modelling can play in each case.
- Training days during which company personnel obtain hands-on instruction in modelling tools appropriate to the topic being addressed that month. The aim is both to develop the modelling skills of technically-oriented employees and provide management with an appreciation of the technology's capabilities.
- In-house assistance with the application of featured tools within actual projects (including the loan of a suitably configured computer).

In this way members are alerted to the issues that present obstacles/ opportunities for their business, develop skills in tools that address these issues, and receive help to translate the outcomes into practice; all on a repeating monthly basis. The in-house assistance activity has proved particularly successful, with companies often purchasing the SESG loan computer in order to ensure that their newfound work practice can continue unhindered by IT-related problems.

In addition to the monthly activities, information has been disseminated via a newsletter (HotNews) and a dedicated Web site (www.sesg.strath.ac.uk). SESG also contributes regularly to professional events organised by others thus enabling dissemination to the wider community of non-members.

Taken together, these technology transfer mechanisms impart insights into the issues relating to sustainable development, foster skills acquisition in advanced modelling methods and tools, and allow the industry to obtain on-the-job application experience. Additionally, the close relationship with researchers at the University of Strathclyde has enabled member companies to participate in EC research programmes and facilitated the timely dissemination of research projects outcomes.

OUTPUTS

SESG activities to date have given rise to several significant outcomes as follows, each relating to a specific performance target established at the project's outset.

- Membership has grown to 43 companies, with 583 individual members registered to receive information directly from SESG.
- Most member companies have adopted the technology and are reporting an expansion in the scope and depth of the work they are undertaking.
- 418 members have attended seminars, while 176 of these have received software training inputs.
- 147 supported technology deployments have been completed, each involving in-house assistance with the application of modelling and simulation within live projects.
- 26 new jobs have been created, mostly through the employment of new graduates possessing refined modelling skills (18 of these relate to people under 25 years of age, while 11 are women).
- 2 companies have released staff to pursue higher degrees as a result of technology uptake.
- 7 companies have published papers at international (5) and national (2) conferences on the results from their modelling work or the impact of modelling on their business.
- An investment of the order of 1.2M by member companies in R&D and innovation.
- An increase in local software sales amounting to 100,000.

These achievements are significant considering the construction industry is male dominated (88% of employees are male in Scotland), and has traditionally lower levels of investment in R&D and innovation than other sectors.

At the outset of the project several mechanisms were adopted to transfer the technology into practice. In addition to traditional approaches (seminars, workshops

Date	Description	Numbers attending		STDs
		seminar	training	initiated
June 2002	Energy efficiency products, methods and assessment techniques.		11	18
July 2002	Indoor air quality issues and assessment techniques.		10	6
August 2002	Design integration and the role of integrated modelling.	23	13	17
September 2002	Building regulations (Part J) and the role of modelling and simulation.	59	30	14
October 2002	Lighting technologies and systems design.	17	9	3
November 2002	Life Cycle impact assessment.	11	30	2
December 2002	Building-integrated renewable energy systems.	23		5
March 2003	Fire engineering	15	7	6
April 2003	Climate change abatement.	40	6	7
May 2003	Achieving sustainable cities.	17		
June 2003	Small scale renewable energy systems.	25	10	12
October 2003	HVAC and control systems design.		14	10
November 2003	Outdoor air quality assessment.		4	3
December 2003	Acoustics design and evaluation.	18	6	4
March 2004	Value engineering.	19		8
April 2004	International developments in design and advanced modelling.	38	10	3
May 2004	Building regulations and new energy systems for domestic dwellings.	113	6	4
June 2004	Lighting systems.		10	12

Table 1: SESG Activities

and newsletters) more novel approaches were employed in the form of Internet-based advice and in-house supported technology deployments.

Table 1 tabulates the events and support activities undertaken. As can be seen, the regular seminar/ training/ supported technology deployment cycle was well supported throughout the project.

A typical seminar will have three or four speakers with expertise in the topic being addressed. A key aspect of this is that the speakers are not limited to the developers and sellers of software tools, but encompass the users community. For example the seminar on building regulations included speakers from the Scottish Executive, BRE and the University of Strathclyde. The aim of a seminar is to introduce a topic and illuminate how modelling tools can be used to address the issues.

Seminars are followed by training in specific software tools. This allows those present at the seminar to develop new skills within a fully supported academic environment. For example, following on from the building regulations seminar training events focused on tools that offer a regulations compliance checking capability.

The final element in the monthly cycle is the supported technology deployment. At the project's outset several barriers were identified to the use of simulation, including the availability of suitable hardware/ software and application know-how. These barriers are addressed by providing a company with an appropriately configured computer and an application specialist. Typically, an activity will focus on a key aspect of a design, for example natural ventilation or the integration of a renewable energy technology. Typically the loan computer is left with the company for a week or two, enabling practitioners to explore more design options than would be possible if the work was outsourced.

WHY HAS IT WORKED?

A survey of members was undertaken to ascertain the elements of the program which had enabled them to routinely use simulation. These responses fall into two categories: drivers and advances.

Drivers are the external commercial and legislative demands faced by companies, for example the upcoming EPBD legislation. Advances are related to software development and user skill base changes.

Drivers

Commercial applications of simulation are geared towards increasing the service available to clients, and staying competitive as a company. For example, in enabling better design through a computational approach a company can predict reduced energy consumption in final buildings or reduced environmental impact of a building. Key drivers include:

- International protocols: *e.g.* Kyoto and Local agenda 21. These increase the political drive for a sustainable, low carbon economy without giving detail as to how this should be achieved. In doing so there is a popular perception that good design is equivalent to low carbon/ life cycle cost.
- National legislation/ schemes: *e.g.* building regulations, EPBD, BREEAM, LEED. These drivers are more specific in their impact as there are clear pass/ fail criteria. An important aspect of many of these schemes is that there are degrees of pass, *e.g.* for the EPBD a highly energy efficient building will be A rated and a building which only satisfies the minimum regulations may only be a D rating.

- Commercial pressures: *e.g.* type of procurement, company development. In the UK there has been a move towards costing based on the life of the building for government projects. This has increased the demand for an ability to calculate annual running costs. Additionally, there has been an increased desire by companies to bring simulation work in-house, to increase value and control of the process (*i.e.* cheaper and quicker design - two SESGs three key aims).
- Design pressures: *e.g.* increasing complexity, new partnerships. The integration of novel features in buildings: double skin facades, building integrated renewables *etc*. In combination with these new technical demands companies are increasingly working in partnership with others in the design team. This has lead to calls for performance quantification on timescales which can only be delivered upon if the work is undertaken in-house.

Overall, these drivers have resulted in clients demanding more sustainable buildings and reduced life cycle costs, with the aim of an increased profile for their 'green' building. Counteracting this is a desire for the overall capital cost not to increase. As a result the desire by practitioners to be able to quantify building performance as early as possible in the design process has increased; thus they can make informed decisions about design changes and their impact on the overall design.

However, the use of simulation at early design stages is not risk free. There are many unknowns and although the impact of assumptions can be quantified it is not routinely applied. Instead the practitioner relies on their knowledge and new barriers to uptake are encountered [Hobbs *et al*]:

- increased risk of liability to the practice,
- unfamiliar working methods,
- lack of fundamental knowledge, and
- perceived increase in workload.

These barriers have been tackled by improvements in training, management and software developments.

Advances

To successfully employ simulation tools advances are required in several areas including a skilled user base and software applicability for design work. Surprisingly, member companies have wanted to move in the direction of computational tools but have been discouraged by the interfaces to these tools. This required specialists to use the tools and also understand the output, translating the results into meaningful information for the design team. With increasing numbers of graduates with simulation skills there existed a good platform to tackle issues related to the user.

In the UK the TCS/KTP (Teaching company scheme/ Knowledge transfer programme) [KTP] has been instrumental in allowing companies to bridge the gap between academia and practice. Several SESG member companies have used TCS/KTP associates as a mechanism to enable them to embed simulation into their existing procedures. This has been augmented by improved training and QA mechanisms - *i.e.* the use of simulation in a company has not been the sole responsibility of an engineer (usually a recent graduate). In one company the use of simulation was curtailed when the only trained user left to work at a competitors office.

Detailed QA/ training schemes have been adopted by member companies, and include steps questioning the need for simulation, the specification of what design question should be quantified and feedback to ensure that the model was fit for purpose. To minimise the impact QA has on model development time (as is often the case with QA procedures) companies have examined methods by which reporting can be automatically generated. This has included engaging developers to make changes to the reporting available from their tools and creating bespoke tools. The latter option is often required as companies use a variety of software depending on the problem to be solved, but want a standard reporting mechanism. For example, this was achieved by using spreadsheets in one company [McElroy *et al*] and a bespoke interface in another [Hobbs *et al*].

Finally, simulation software provides detailed information on the problem analysed, but often does not directly answer the design question. For example, can an office be naturally ventilated? To answer this the practitioner will have to assume openable areas and then test this hypothesis with say an air flow network. This will then tell them the air change rate: but this varies over time and what will be the air distribution within the space? So how does the practitioner answer the design question: sometimes it may work, and sometimes it will not? Practitioners have started to be able to translate this information into their designs. They will often ask for a CFD run or two to characterise how the air is distributed in a space, and will be able to make judgements on what the risk of failure is. As such there is still a gap between the academic simulation tool development and their practical deployment.

<u>FUTURE PROGRAMS</u>

Two complimentary programs have been funded and are now operational in Scotland. The first is the continuation of the SESG and the second in the national sustainable architecture program SUST.

SESG

Despite the successes of the previous phase there are still significant barriers to the widespread adoption of simulation tools for energy systems design. The old barriers still exist but have been augmented (or maybe redefined) by the new barriers described above.

Perhaps one of the largest barriers is the lack of consistency and standardisation in this area. It is often quoted that two different users of the same tool will get two different answers to the same problem. If these issues can be tackled practitioners will have the confidence to use and defend the results from simulation tools. Perhaps, with future updates of Bestest, the emerging CEN standards and user testing [Macdonald *et al*] there will be facilities to achieve this.

The next phase of the SESG aims to consolidate and expand the activities program. The monthly events cycle (topical seminars, program training and in-house support for deployments) will be continued, but with a new focus that addresses those issues that are likely to most impact on businesses. These issues include but are not restricted to:

- The European Energy Performance of Buildings Directive. This legislation will be enacted in January 2006 and will require urban energy performance to be predicted, monitored and reviewed on a regular basis. This is a signal development because, for the first time, the requirement to model will be enshrined in law.
- Low carbon technologies ranging from conventional devices such as heat recovery schemes through novel systems such as combined heat and power and air/ground source heat pumps.
- Demand reduction in its various forms from increased equipment efficiency to demand side management using remote switching technologies.
- Citizen health and wellbeing with the focus on tools for the study of environmental emissions, air quality, human comfort and evacuation.

The training programme will focus on how design issues can be addressed by computational methods of different degrees of sophistication. This will entail the design of training courses which do not focus on a single tool rather the complex issues regarding performance quantification at all design stages. An example training course may start with a spreadsheet method, move onto a basic computational tool, and then finish with an dynamic building simulation. In this way the practitioner is shown how to tackle design issues with available tools, with the added gain of knowing how and when in the design process to employ which method.

Alongside the training programme the in-house modelling support scheme will also operate; SESG will supply equipment and personnel to assist practitioners in the use of specific simulation tools. This process identifies suitable live projects where simulation can benefit the design team. A suitably configured computer is supplied to the practitioner with an expert in simulation use. The practitioner is then supported with their use of the software with the assistance guaranteeing that there are no barriers to the use of the tool (*e.g.* dealing with incomplete data, translating design questions into modelling approaches).

Additionally, performance assessment methods will be reviewed in an attempt to gain consistency in tool use. This will be monitored in member companies to test the efficacy or not of new procedures.

SUST

Sust. [SUST] is a Scottish Executive funded project, devised by The Lighthouse [The Lighthouse], to be consistent with its approach to sustainable development as outlined in the 'Meeting the Needs' document [Scottish Executive]. Sust. aims to promote a sustainable approach to design in the built environment and to assist all those designing and commissioning buildings in delivery of buildings that meet expectations.

Despite the fact that sustainability is at the heart of Government Policy across Europe and the fact that the majority of public and privately funded projects are currently being delivered (with good intention) against design briefs that call for sustainability, the number of truly sustainable buildings being delivered is relatively low. Research shows that in practice, perhaps due to lack of control or poor communication, there persists a tendency not to see things through [Scottish Executive]. The reasons for this are many fold and range from:

- lack of understanding of what sustainability means;
- over simplification of the issues;
- mis-information regarding sustainability;
- failure to ensure that the sustainable design intent is carried through and revisited at each stage of the process.

Many of those commissioning and designing 'green' buildings think of sustainability as an add-on, such as the addition of anything from insulation to heat pumps, wind-turbine or photovoltaics, to a traditional design. Rather, sustainable development is a process that requires constant vigilance and re-evaluation at every stage in order to avoid 'dropping the ball'. This may include new and renewable technologies, but only if appropriate.

The Sust. campaign aims to enable its clients to take a more integrated and holistic approach to the design and management of the built environment with a view to promoting a fundamental shift in thinking about Sustainable design. During a 12-month pilot campaign (2003 - 2004), Sust. engaged key players including: clients, developers, community groups and designers, responsible for building projects and assisted them in the development of unique training, guidance and information to allow decision-makers to make informed choices about sustainable development. Projects were put in place to develop tools, techniques and guidance to assist all building stakeholders to make the necessary changes to their approaches and work practices - in effect to mainstream sustainable development. In phase two, Sust. is seeking to work with kindred organisations such as SESG in order to maximise the potential combined impact at the implementation stage of a project.

Some of the main elements that comprised the Sust. pilot included:

- Green Business Strategies: Assistance on live design projects with a major housing developer and a local authority (PPP schools campus);
- Tools and Techniques: A Green Directory of benign products and services available in Scotland and an Ecological Design Gateway providing access to ecological design support services;
- an international conference on Urban Ecology and education workshops;
- a series of case studies for sustainable design;
- Awareness Raising through training for housing associations and local authorities.

CONCLUSIONS

The SESG project has delivered significant results against its agreed targets. In doing so the SESG is beginning to change the design ethos in construction SMEs towards an in-house performance-based assessment approach, thus reducing design times and generating better design solutions.

This has been achieved by a combination of push and pull. Companies have been forced to update their methods through a combination of client awareness, legislation and competitive need. Additionally, practitioners have through their use of simulation tools helped to define their development and efficacy to the design process.

Two complimentary schemes are hoping to address the complexity of sustainable design by promoting a computational approach. The SESG aims to deliver the capabilities to practitioners, while SUST aims to engender a need for performance quantification in practices without the capabilities to adopt the tools in-house.

A by-product of of this work is a reduction in greenhouse gas emissions resulting from building operation. It has been estimated that the saving over the past three years of SESG operation is of the order of 150,000 Tonnes CO_2.

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