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Simulation, no problem, of course we offer this service! (observations on firms who have worked to make this true)

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ABSTRACT

Reports of technology transfer initiatives often only tell part of the story. The actual benefit of such initiatives to practitioners aspiring to use simulation to improve their work practices, while at the same time increasing profits and enhancing their reputation within the design community, is less often discussed.

The Scottish Energy Systems Group (SESG) has been assisting a number of large and small building design and construction companies with the transfer of simulation technologies into their businesses. The aim is to show that simulation can make the design process "quicker, cheaper and better", and that simulation can become a mainstream design activity. All participating organisations readily accept the need for changes to current design practice in order to achieve this, but few are prepared for what it means in practice.

The paper focuses on the practical experiences of a number of professional firms striving to use simulation to deliver information of value to their clients. It exposes issues such as limitations in existing working practices and the mismatch between language routinely used by facilitators and trainees as well as their different expectations.

The paper also discusses the differences observed between incremental implementation of simulation within practices and firms who wished to "jump in at the deep end". Lastly, it addresses the dilemma of how to move simulation tools into the already busy schedules and overloaded programmes of design practices - successfully.

INTRODUCTION

Reports of technology transfer initiatives are often presented as dry statistics and organizational charts which, while appreciated by funding bodies, tell only part of the story. The actual benefit of such initiatives to practitioners aspiring to use simulation to improve their work practices - at the same time increasing profits and enhancing their reputation within the design community - is less often discussed.

Over the last three years, the SESG has been assisting building design and construction companies with the transfer of simulation technologies into their businesses. The aim is to show that simulation can make the design process "quicker, cheaper and better", and that simulation can become a mainstream design activity. The companies involved range from small, specialised companies operating within niche markets to large multi-disciplinary organisations of international repute. All acknowledge the need for changes to current design practice, but it has emerged from this study that few were well-prepared for what this would mean in practice.

The paper makes use of case study material from a broad range of technology transfer deployments and uses the experiences of a number of professional firms attempting to use simulation to deliver information of value to their clients. The aim was to explore whether or not it is possible to deploy simulation successfully in practice and to discover what key steps might make the difference between success and failure. Along with the bruised egos and raised voices there were the serious issues of the short and long term effects on productivity and existing working practices into which new ways of working were being imported.

Also highlighted are exposes of the mismatch between the language routinely used by trainers and facilitators for the various simulation tools deployed and the trainees - glazed eyes indicated an unwittingly excessive use of jargon, not to mention differences of opinion on the meaning of "user friendly" and "intuitive". Similarly, the unrolling of fifty sheets of plans and sections for a first "simple modelling exercise" indicated that misconceptions exist on both sides.

While some practices are willing to implement simulation incrementally, to give their staff the time and resources to build confidence and the practice's partners time to evolve work practices, we found others

that wanted to jump in at the deep end. Although it is easier to nurture the former, sometimes the latter proved unavoidable and results varied.

Lastly there is the issue of how to move simulation tools into the already busy schedules and overloaded programmes of design practices.

SESG RESUME

The Scottish Energy Systems Group (SESG) is a consortium of simulation specialists, professional practices (Architectural, Engineering and multi-disciplinary), facilities managers, local authorities and construction firms. The members who supply simulation skills and tools and the members who subscribe have a mutual goal that is to implement simulation-based technologies within business in a way which limits risk (commercial and professional) and provides easy access to a range of tools and support for evolving new ways of working.

The usual way this is accomplished is for members to approach SESG with a specific project in mind and depending on the nature of the work SESG would arrange for one or more of the SESG specialists/ vendors to support the technology in their offices using one of several "loan" workstations pre-configured with the relevant software. Where required, SESG would also arrange for, and support, training at a convenient venue. A more detailed description of SESG can be found in [1], [2].

FORCES OF CHANGE

Technology transfer initiatives exist to fill a perceived gap between emerging technology and current practice. Let's face it, if deploying simulation within professional practice were straightforward, consortia like SESG would not exist. If the market were more mature, funding bodies would be less interested in providing support. Professional practices perceive a significant risk in deploying simulation. There are indeed dragons to do battle with for early adopters of such technology. When they have mastered simulation and made it part of their ongoing work practices they often find that they have changed the way in which they carry out their business activities.

So why would the professional practices want to join such a consortium and/or to seek to change the way they do business?

- Clients are asking questions which many professional practices find difficult to answer with their current skills and support infrastructure. The ASHRAE and CIBSE guides no longer hold all of the answers and indeed CIBSE has responded to this by the publication of an Applications Manual devoted to Building Energy and Environmental Modelling [3].
- Competition is driving the construction industry to consider alternative approaches. In Great Britain there are a number of firms which specialise in simulation-based support of the design process. The increasing success of such specialists has caught the attention of other professional firms. The existing approach has been to employ these specialists as consultants, but at some point, the question of doing such work in-house arises.
- Changes in building regulations in the UK have also created opportunities. The use of innovative designs and innovative materials, if the design teams can back-up any claim that the alternative produces less atmospheric emissions than a conventional design. This move towards performance rather that prescriptive-based regulation seen as a significant step in changing working practices.
- In addition, the balance between capital and running costs is being reconsidered by design teams bidding on private finance initiatives (PFI). PFI uses a mix of public and private finance to for example, design, build and run a hospital complex over a 30 year period. In such a context design teams have an incentive to use alternative designs which have lower running costs.
- There is a supply of technically proficient graduates who are not at all reticent about advising their "steam-driven" colleagues and thus able to adopt a more prominent position in the team at an earlier stage in their careers. There is also an active and growing market in such skills and which partners are increasingly aware of.

CASE STUDIES

In this paper, the authors hope to convey, by way of case studies, what actually occurred in practice when SESG members took part in the deployment of simulation-based tools and/ or expertise. The stories which follow are true with the exception that some of the details have been obscured to preserve the confidentiality of the participants.

A SMALL ENGINEERING PRACTICE

Over the last two years, the integration of advanced modelling into a small environmental engineering company has been achieved through the SESG. The first stage involved the company agreeing to send two

junior staff members to a training course on the simulation packages identified as best meeting the company's needs. Following on from this, in-house training, centred on a specific project was undertaken.

The decision to move to a modelling-centred approach for this company is based on the nature of their business. In this case, the practice specialises in less conventional projects where simulation has assisted the design of buildings with ground source heat pump heating and complex natural ventilation strategies. Simulation was seen as essential in developing the design on these projects, representing the only available means of analysis that allows the practice to meet client needs and deliver leading edge design solutions.

The young trainees were identified by the company as being enthusiastic and well suited to the challenge. However, it soon became evident that there was an urgent need for their managers to become conversant, if not proficient, in the tools in order to engage fully in the process. Specifically, the managers needed to combine their existing skills and experience with the newly adopted procedures to ensure that quality assurance and indemnity insurance were not jeopardised. As a result, in order to oversee the new practices, the managers were trained to the same level as the junior staff. Although they admitted to finding the training 'challenging' in the extreme, the company can now proceed with greater confidence, armed with the knowledge required to modify QA and design procedures accordingly. In spite of initial concerns over the cost-effectiveness of sending senior staff for training in tools that they would not use, they are now reaping the benefits of this additional investment in staff time due to a more coherent approach than would have been possible otherwise.

In this case, the ultimate intention is to integrate the use of simulation in order that it can be available to every client. Experience to date has assisted the company to identify the following as being of critical importance in integrating simulation within a small practice, to ensure that simulation does not adversely affect either the design process or the economics adversely:

- It is easy to become mesmerised by the power of a simulation tool, for this reason, the objectives of the exercise must be clearly defined, and a novice user must accept their limitations and allow expertise to develop gradually. Support is vital at the initial stages to ensure that an analysis is well planned and executed. However, this support can come from inside the organisation as well as from specialist modellers and it is vital to engage staff at all levels of experience in order to maximise the benefits.
- Quality assurance procedures are crucial to ensure that the novice modeller can be confident about the results. These procedures also ensure that the building performance is analysed according to appropriate criteria.
- Refresher courses are useful as the practice evolves, especially if the tools they are using are also evolving.
- There are risks associated with having one staff member carry out most of the simulation work within a small firm. This can place that staff member under considerable stress if he or she is working on multiple projects. It also limits the flexibility of the firm in scheduling work.

The experience of this small practice not only confirms the need for appropriate training and subsequent support in deploying simulation, but also recognises the fact that if support is available, reliable results can be obtained quicker and better than by using traditional methods, thus saving the company money through reduced design development.

As a result of SESG input and the investment in new working practices the firm is now free to explore technical aspects that it could only guess at before. But for other small practices the case study points out a cautionary note:

The move should not be taken lightly, the main cost in undertaking this commitment is not hardware or software, but in staff training. In this case it was quickly established that there is a need to train staff at all levels in an organisation. It is also important to ensure that skills are spread as evenly as possible throughout the organisation in order to avoid the problem of losing capability if staff leave. Thus, for a small practice, the initial start-up cost in terms of staff time is estimated at around £25,000 based on formal training and time lost in moving from the old to the new methods.

Without appropriate support this cost could easily double.

A LARGE ARCHITECTURAL PRACTICE

Another SESG member company has recently taken the decision to incorporate building performance modelling within its architectural design procedures. The company, a large practice with offices throughout the UK, has decided to make this commitment nationwide, in order that the company can in future draw on the necessary skills from its offices across the country.

The aim is to become one of only a few architectural practices in the UK that include thermal, lighting, structural and cost analysis methods as an integral part of the design process. In order to achieve this goal, the practice has launched a two year programme with the aim of developing an in-house simulation capability [4]. The company recognises that many barriers will have to be overcome (financial, training, personnel issues, etc.) and these are being assessed.

With support from SESG, the practice has invested in a new member of staff to facilitate the rapid adoption of a formal modelling approach. The company is IT literate and a key factor is seen as the need for the development of unhindered transfer mechanisms for CAD based design modifications to simulation tools.

The practice is also aware of the risk of error associated with adopting default engineering values in cases of uncertainty and has taken two key steps to eliminating the risk of trainee modeller error.

- Firstly, the company is identifying and adopting recommended engineering assumptions for use in all cases of uncertainty [5] and is drawing up a detailed set of procedures and working practices in order to minimise the risk of user error.
- Secondly, in order to facilitate the unrestricted use of simulation throughout a practice with limited engineering competencies, the medium term goal is to develop a custom- built interface. This interface is intended to ensure that CAD data are reliably transformed into the data structures used by the simulation tool and that QA and abstraction procedures are followed.

Initially, the practice did not have a full in-house capability or resource to undertake the modelling it desired, and assistance was sought from SESG. This offered an opportunity to address thermal modelling and visual comfort aspects on a live project using the skills of the new member of staff working with SESG personnel. The outcome improved confidence in the integrated modelling approach and gave rise to the decision to adopt the approach.

The next point of SESG support was to locate an expert in the simulation tool work with the firm to further evolve the customised interface. Interestingly, the custom-built interface includes extra documentation and cross-referencing which were found to be be useful for a range of users of the simulation tool.

As with the previous case study, the decision to evolve a simulation-based practice was not taken lightly. Although operating with a large staff and a relatively high turnover, there are still high costs and potentially greater insurance risks in terms of maintaining control and overseeing the new work practices. The practice is addressing these issues through the development of quality assurance procedures and the further development of the tailored interfaces. It is now proceeding to build up an in-house simulation capability as a matter of course. The practice sees this as an essential capability that will be increasingly demanded by clients.

A MEDIUM SIZED ENGINEERING PRACTICE

Another SESG member company has recently taken the decision to incorporate building performance modelling within its core-base of skills. This company has a main base in Scotland (around 60 personnel), with smaller offices throughout the UK (totalling approximately 100 staff). Mindful of previous experiences where the company had a small simulation team that was divorced from the design process and which became isolated as a result, the company is now determined to avoid future reliance on a specialist team based in one office. Rather, they are launching a new initiative which they call 'gateway working', whereby staff in all of the company's offices can communicate and work freely on the same projects from different bases. This mechanism, once in place, will allow clear lines of communication and will ease the way for integrating simulation into day to day practices.

In order to support this scheme, the company has embarked on an intensive training programme involving eight staff from its two main offices undertaking sustained training of a half to one day a week over a period of months, with staff obligated to ongoing individual study between formal sessions. In addition, in order to test the effectiveness of the training, a live project is being used as controlled test-bed for the theory, whereby the trainees are undertaking a series of supported studies on a refurbishment project on which there is a large amount of monitored information available to support the users in evaluating the validity of the simulation outcomes.

One pattern observed during this part-time training approach was that staff who carried on working with the simulation tool between training sessions showed a marked improvement in comparison with other staff whose workload did not allow this. Another pattern identified was that hypothetical studies, as necessary as they are for learning basic skills, do not engage staff to the degree that actual projects do. Where skills were not quite up to working on a live project, for example if it involved a tight time-scale or was overly complex, a review of a recent project proved a

superior vehicle for training.

As with the case study of the large architectural practice, the decision to engage in simulation-based projects was considered thoroughly before making a final decision. The company is confident that the adoption of a 'gateway working' approach will ensure that simulationists within the company will still be engaged in the design process as full members of the team and that they will still perform an engineering role.

In addition, the concept of 'gateway working' suggests a further evolution of simulation tools will be required. For example, project managers of simulation-based projects will need to co-ordinate project databases, documentation and support materials across many sites. Distributed simulation work has been a point of (largely) theoretical discussions, 'gateway work' will certainly identify limitations in how current simulation software can cope with distributed projects. It is thus anticipated that monitoring of the evolution of this project could yield long overdue answers to key questions and problems relating to full integration.

A LARGE, MULTI-DISCIPLINARY DESIGN PRACTICE

SESG was asked to support the integration of simulation in a large international, multi- and inter-disciplinary design practice. This practice has in-house architects, civil/ structural and building services engineers and already adopts an integrated approach to design on many projects where it forms the main contribution to the design team.

In this case, SESG was asked to assist the architects and engineers on refining the daylighting and mixed-mode ventilation strategies for an auditorium in a new building that was already under construction. It was initially anticipated by the SESG staff, that moving in simulation to an already integrated practice would be a straightforward task, given that the practice would already have in-place a system to support integrated working. However, the outcomes were not quite as anticipated and for the following reasons:

- It proved difficult for the SESG staff to maintain momentum with the project due to the fact that access to the company staff was restricted due to the project being on site staff being heavily engaged in this activity. As a result, the SESG staff ended up doing more of the work and so the exercise became more consultancy and less training orientated.
- The company does all of its architectural drawings on computer, and was able to provide a detailed CAD model to assist with the exercise, however this proved difficult due to the way in which the model had been constructed.
- Despite the fact that the company is in name a multi-disciplinary practice, it became evident over time that the architectural arm dominated and the engineering divisions provided more of a support role than SESG had anticipated. However, the engineers felt strongly that by engaging in simulation, they could have more influence over the design. Unfortunately, the pace of the project resulted in the novice simulationists being pulled in multiple directions and this caused some concern as the pace of activities resulted in a lack of control over QA, which was often undertaken later in the process than would be ideal.

This exercise indicated that it is important for companies to start slowly and to accept the limitations of trainees. The existing CAD model could have better facilitated the development of the thermal and lighting simulation models if it had been constructed in a more structured manner. This had a major effect on the project timescale and has been highlighted to the company as a key issue with regard to making a simulation capability viable within the company. If CAD models were in future constructed to facilitate export to other tools, then timescales would be significantly reduced.

For SESG the deployment highlighted the fact that it can be perilous to assume that because a company has a multi-faceted capability it will automatically operate in an integrated manner. Notwithstanding office politics and hierarchies, existing procedures can make it more difficult to integrate new methods than might be expected.

The issues highlighted by this study have encouraged the company to re-assess what tools it needs and how these might best be incorporated into the process. There is also a desire to examine the possibility of improving dialogue between architects and engineers and so the position of an 'archi-teer' to bridge the identified gap is being created.

UNEXPECTED FINDINGS

More often than not, SESG member firms wished to deploy simulation within projects which demanded mature simulation skills and evolved working practices as opposed to projects which were of a complexity readily grasped by a novice. This was usually not a bad thing because the benefits of exploring simulation within the context of a real project are significant. It did imply that the SESG support staff or vendor

would be able to step in and ensure that the work was completed on time and of reasonable quality. Few vendors are willing to take on such risks and not every member firm was initially ready to devolve such risks.

There was a marked difference in the expectations of managers and the trainees of SESG member firms with regard to the required time investment in both training and follow-up self learning with managers often expecting too much too soon. There is a significant difference between the skills acquired in two or three days of training and that required to use simulation within the complexity of the design process. Vendors often fail to point out that several weeks can be required for useful working practices and communication channels to become established.

Some SESG member firms, during their transition between the use of specialists consultants and a substantial in-house capability found it easier to rely on repeated technology deployments than to ramp-up their in-house skills. This tended to happen in projects which were somewhat more complex than their skills base. Staff were (sensibly) apprehensive about stretching their skills and so relied more on the specialist support staff than is ideal if truly aiming to expand a skill base.

Different companies have different ways of evolving working procedures. Some write detailed procedural documents, some evolve their procedures as they evolve their understanding of the tools they are evaluating, some claim it is not yet an issue. One successful technique was for managers to undertake the same training as their staff even though they would tend not to be directly using the tool. This appeared to go a long way towards enhancing the companies' understanding of how to most efficiently deploy the tools and the sorts of information which could be gathered for a given resource. It also clarified concerns about QA, indemnity insurance and timescales.

In another case, the introduction of detailed simulation caused considerable embarrassment because the additional performance information that the staff were generating was beyond the capacity of their managers to absorb. In the end, this company opted for a simpler tool for use in-house and the use of outside consultants for more complex projects. Ultimately, member firms had to reach an agreement regarding what could reasonably be expected of trainees, what part simulation could play in the design process and which elements of a design required 'expert' input.

There was sometimes a mismatch in the expectations of managers and SESG support staff/ vendors for what could be accomplished within a technology deployment within existing working practices and information sources. A classic case was an initial deployment for a project that the design team had been working on for a year and where the CAD files spanned several CDs. It was assumed that: a) other parties could easily grasp the complexity of the project, b) that the CAD files were complete and error free, c) that the information they used for a simplified steady-state assessment was suitable for supporting detailed thermal and visual simulation models. This proved much more difficult than was expected in practice.

More than once, technology deployments illustrated how misunderstandings in design intent could distract design teams and support staff. Dozens of assessments were carried out to explore the sensitivity of one design parameter when it was, in fact, a different facet of the design which was of concern to the design team. At the other extreme a tool usually used for directed explorations of specific design options would be coerced to attempt n x n x n parameter excursions by support staff who were not in a strong position to question the methodology of the design team.

Many firms who were prepared to pay a premium for engineering software and who assumed that this would reduce training costs and expedite their use of simulation within the design process were disappointed. Simulation software is only one part of the equation. Many of the issues of simulation deployment identified by [5] are not yet embodied in simulation software and require attention to other aspects of professional practice. Conversely, member firms who began with limited expectations of simulation and a longer term view were able to use their membership in SESG to explore a range of possible approaches and to build on these experiences to re-mould their working practices and range of services.

CONCLUSION

In spite of the fact that the above case studies highlight the problems of deploying simulation real time within the design process, all of the companies involved in the SESG are still pursuing an integrated design process that includes modelling. Having been exposed to simulation in this protected environment, they all acknowledge that there are undoubted benefits. Some, having been exposed to one tool have now decided that it is worth persevering with that system (perhaps because they perceive a steep learning curve with all such tools), others have tested more than one tool in an attempt to find the ideal for their needs. One thing is clear, however, and that is that all

participants recognise the benefit of this type of targetted training on live projects over the type usually supplied by vendors which tends to focus on exemplar projects which run smoothly, unlike real life design situations.

Thus, the SESG mechanism for technology deployment has proven itself to be a powerful device, largely because it provides support while protecting the training is an integral part of a familiar process and is undertaken in the real time, real scale context of design practice.

It should also be noted that SESG encourages all participating vendors to allow potential customers to try out software before they make any serious investment in order to reduce the risk to companies of purchasing an inappropriate tool. In other words the benefits of the software should be demonstrated in a commercial setting before money changes hands. In this way, companies are also able to evaluate the fitness for purpose of alternative programs before making a decision to invest.

The case study practices have made a commitment because they see simulation as the only way of addressing the design challenges with which they are now faced. They believe that if they do not accept this challenge now, they will be overtaken by their competitors.

A key message from all four is that while machine deployment and in-house training will ease the way, they nevertheless face a transition phase, between old and new practices while still meeting day to day programme requirements and deadlines. They have all expressed a need for on-going support during this transition.

It is difficult to maintain a balance that does not adversely affect productivity. This may explain why up until now, most of the associated activity has been in larger practices.

- Finally and in conclusion, contemporary modelling systems can be cost-effectively deployed where appropriate support is available.
- The largest portion of the cost relates to staff training, not to the acquisition of hardware and software.
- A change in work practices is needed if the profession is to move to a new best practice based on a computational model of design. Barriers and bottlenecks can be minimised through training support and by setting achievable goals.

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