# PRECONDITIONS FOR THE USE OF SIMULATION IN M&E ENGINEERING

P. de Wilde[1] and D. Prickett[1]
[1] School of Engineering, University of Plymouth
PL4 8AA, Plymouth, United Kingdom

## ABSTRACT

This paper reviews the current situation in M&E (services) engineering in the United Kingdom considering the use of simulation in the building design and engineering process. It maps out the different forces that currently act on the deployment of simulation tools in building services design and optimisation. Surveys and in-depth interviews have been used to investigate the factors (key value drivers) that influence the application of simulation technology. The results have been used to develop a deployment/non-deployment flowchart for the use of simulation tools in the building design and engineering process.

The flowchart developed in this paper identifies a set of barriers to the use of simulation in daily, general M&E practice that needs to be addressed. Interestingly many of these barriers lie outside the realm of tool development/software engineering. However, if simulation is to really go mainstream in building design, research and development work is needed that creates the right preconditions for the expert consultant to employ this technology. This requires interdisclinary research that blends ongoing technological efforts in the field of building simulation R&D with design process management.

## KEYWORDS

Practice, deployment/non-deployment, application

## INTRODUCTION

The use of building performance simulation in design practice is one of the major pathways for this technology to actually improve the quality of buildings, impacting on their occupant comfort, energy efficiency and emissions. There are regular reports on the successful use of simulation in the design process. However, the actual cases for which these successes are being reported are often high-profile, special buildings, which are not representative of the average building design project; see for instance the work by Choudhary et al (2008). Many mid-size, regular industrial projects still fail to enjoy the support of simulation, and simulation is almost never used in the design of regular housing projects.

In the building science community there are ongoing efforts to better integrate building simulation tools into building design practice, see for instance Morbitzer (2003), de Wilde (2004), Prazeres (2006) and Hansen (2007) for some recently completed PhD thesis in this field.

Much of this work is based on the premise that simulation tools will yield information that is beneficial to making better informed design decisions by the design team and lay clients**,** and allow for optimisation of building system sizes and control. As such, it is often assumed to be a ‘sine-qua-non’, almost mandatory instrument that has to be used. Yet it must be observed that a lot of the research lacks hard empirical evidence on use of simulation in real building design projects, and is based on quotes and observations from other building science researchers rather than a need formulated from the actual building engineering practice. While simulation can undoubtedly play an important role in building engineering, it is only one of the instruments available to the experts that design buildings. It therefore is relevant to study when simulation tools are used to inform design, as well as to analyse when they are deemed superfluous.

## OBJECTIVES

The main objective of the work reported in this paper is to review the actual use of building performance simulation in the building design process, as reported by consultants in the services (M&E) engineering / building physics / energy systems disciplines.

From reports on actual use of simulation tools, or the lack thereof, a deployment/non-deployment flow-chart for the use of simulation tools in the building design and engineering process will be developed.

It is hoped that this work will provide a better handle on the actual needs from industry where it comes to development of novel tools, replacing the ‘perceived needs' as formulated by the building simulation research community.

## APPROACH

The deployment of building performance simulation tools in the building design process has been studied by means of a three-pronged approach:

1. A survey amongst practitioners.
2. The development of a schematic deployment/non-deployment flowchart for simulation, based on the survey findings.
3. A further review of deployment of simulation, and further development of the flowchart, by means of in-depth interviews with a small number of practitioners (note the reviewers of BS'09: this section is still ongoing; final results will be incorporated into the final version of the paper).

Questionnaires have been sent out to consultants in building services engineering with leading UK companies, including ARUP, Buro Happold, Faber Maunsell, Hoare Lea, Mott MacDonald.

Through the questionnaires, information has been gathered on the use of simulation in actual projects. The respondents have each been asked to select three projects that were completed in the time frame 2006-present. To get a spread of projects, the respondents were asked to select one in each of the following categories:

A. project in the cost range of less than £ 5 million;

B. project in the cost range of in between £ 5 million and £ 20 million;

C. project in the cost range of more than £ 20 million.

The respondents were not required to name the projects, ensuring anonymity of their replies and identity.

For each project the respondents then were asked a range of yes/no and open questions, covering a general description of the project, the use of prominent building features, and the deployment of simulation tools. If simulation was indeed used, a dedicated section asked further questions about the context of this use.

The flowchart for deployment/non-deployment of simulation is based on considering and ordering the main arguments for or against use of simulation in the design process. The issues at stake have been simplified into yes/no decisions by the researchers.

The interviews with practioners have been structured as open interviews. Interviewees have been asked to comment more in depth on the why and why-not of using simulation in their projects, and have been asked to provide feedback on draft versions of the flowchart.

## RESULTS

**Survey on the use of simulation**

Twenty surveys were sent out to selected contacts in industry. Seven responses were received. These provide information on the deployment/non-deployment of simulation tools in 21 building design projects.

The results show that simulation is used more in the larger, and/ or highly serviced projects; roughly half of the responses state deployment in the category of projects of less than £ 5 million, again roughly half of the responses report on use in the £5m to £20m band, whereas all projects in the category of over £20 million reported simulation tools being used.

From the responses, reasons given for using simulation found in the returns varied highly. They include:

- Demonstration of compliance with Building Regulations, notably the UK's Approved Documents Part L.
- Demonstration of meeting building category specific requirements, like the Department of Education and Skills (DfES) Building Bulletins 101 (ventilation), 87 (environmental design), 90 (lighting), and 93 (acoustics).
- Demonstration of performance to achieve a desired energy efficiency rating, especially according to the UK's BREEAM methodology.
- Demonstration of meeting the requirements of a specific client, for example the Carbon Trust.
- Calculation of design heating and cooling loads, and other environmental performance aspects like daylighting or condensation risk.
- Verification of:
  - energy use profiles
  - summertime temperatures
  - daylighting
  - light pollution at night
  - acoustic impact.
- Design of naturally ventilated spaces, helping to decide on the position and size of openings.
- Design of ventilation systems, including plenum, outlet openings, flow rates and outlet temperatures.

- Testing of different options, e.g. roof and radiant heating designs, to find an optimal solution.
- Analysis of the performance of systems in foreign, unfamiliar (from an UK point of view) outdoor climates like Lebanon, China, or the United Arab Emirates.
- Analysis of the performance of systems with an unfamiliar indoor climate, for instance tropical rainforest conditions.
- Support of younger engineers, who like to base their work on the use of software.
- Exceptional cases, like mandatory daylight access analysis in relation to the presence of protected animal species (bats).

A potential relation between special building services systems, building physics issues, and IAQ systems (like for instance passive ventilation systems, occupancy sensors, PV panels etc) and the deployment of simulation tools has been investigated, but at this stage proves inconclusive. For instance, some projects that employ passive ventilation systems have been simulated, and others have not. Also, simulation has been reported for a building with not one single special feature mentioned by the respondent.

The respondents reported using a range of simulation tools, including EDSL-TAS, IES Virtual Environment, Hevacomp, CGI, Relux, CFX, Solido, Acoustic Analysis, Dialux, Radiance, and in-house tools BEANS, ROOM and VENT.

The decision to use simulation are mostly taken by the consultancy partner, at an appropriate level - the responses mention 'office technical manager', 'lead engineer', 'M&E consultant', 'director'. However, there is also mention of other project actors being involved, including the informed client, the project architect, facility manager and the contractor, and one case where the architect requested the simulation process. Note that the borders between consultant and designer are sometimes fluid, as indicated by the use of the term 'mechanical design group'.

Most of the simulation work is carried out in-house by the building services consultant. The results indicate incidental involvement of academics (university experts) where appropriate, or external third party consultants.

The use of simulation was reported throughout the design process, ranging from the stage that identifies the client's requirements all the way to the development of the final design proposal (In terms of the plan of work by the Royal Institute of British Architects, stage A to E). Within this range, the emphasis seems to be in stages C, D and E, concept/schematic design, detailed and final proposal.

The final results obtained by carrying out simulation work, as mentioned in the responses to the questionnaire, include:

- Proof of compliance with building regulations (Approved Documents Part L).
- Evaluation of design alternatives, which then are used by the design team to select appropriate options (within an iterative process).
- Demonstration that spaces/zones in the building will perform to satisfaction, meeting the applicable criteria set by the client. As an example, the performance of a naturally ventilated space is given.
- Proof that the proposed building design and/or building services need modification to function properly. Examples quoted are an increase of louvre size and a decrease of the extent of façade glazing to prevent overheating problems.
- The development of novel design solutions, for instance a special space layout (geometry), and its impact on thermal comfort conditions.
- Decisions on materials to be used in the design.
- Some minor changes to the building design, including thermal insulation (U-values, glazing specifications).
- Information on control settings, like air flow rates, set point temperatures.

Some salient comments from remarks sections of the questionnaires are the following:

- It is noted that simulation results need very careful interpretation as well as presentation to the client. Different responses stress that simulation results predict a 'theoretical' performance, not a guaranteed result.
- One respondent stressed the importance of understanding underlying theory and ability of carrying out manual calculations. It was observed that younger engineers have an overreliance on software, and fail to check whether or not their results are sensible. This specifically relates to the environmental control people will exert over their working space and the expectations they hold of this same working space.
- One respondent mentioned a past use of simulation (CFD) to model flue gas temperature and pollutant concentrations in a pre-2005 residential project.
- One response judged a project in the cost range of less than £ 5 million to have been carried out without the use of simulation, "only Hevacomp", whereas others counted Hevacomp as simulation software without comments. This points to a

disparity within the consultancy sector about the definition of simulation tools.

## Flowchart development

The flowchart in figure 1 presents pre-conditions to the use of simulation in three main categories.

The first category is a group that filters out standard building design projects, which can proceed to 'regular' engineering. Standard projects will be highly repetitive, based on proven concepts; the team working on such projects will have experience with the underlying concepts, and therefore less need for additional information on the predicted performance. Standard projects will normally not come with specific questions from the client or architect that require the use of simulation tools. Such projects are also highly likely to meet the building codes and do not need to demonstrate equivalent performance.

The second category is a 'positive' filter for the use of building simulation, looking at how simulation could add value to the design. Reasons for employing tools might include for instance the use of novel and innovative systems, which are outside the experience and/or comfort zone of the consultant (especially younger engineers), or unusual operational conditions (whether in the domain of climate conditions, control, or expected performance). Furthermore, simulation might be deployed for the purpose of underpinning the expectations of the consultant, allowing him or her to demonstrate and quantify expected problems with a building project, or just as a visual communication aid.

The third and final category checks whether or not the context of the design project allows for simulation to actually be deployed in the design project, and as such is a 'negative' filter. This includes checks for sufficient budget, time, expertise, tools, and information to actually carry out simulation work in the context of an ongoing project.

Note that the outcome of the deployment/non-deployment flowchart always is based on a regular building engineering process; building performance simulation is considered here to be an additional activity, where the 'tool' is used to provide extra information for the mainstream activity.

## Interviews with practitioners

Three face-to-face interviews were conducted to get a more overall picture of the deployment of simulation in consultancy practice.

The first important issue raised from the interviews is the importance of the fact that the activities of consultants are to provide added value to the business of the client; their work is not necessarily only focused on building performance. In fact, there are three main forces that act on consultancy and that need to be balanced: cost, time, and quality. See figure 2.


*Figure 2: forces acting on consultancy work*

The interviews stress the fact that building services generally account for 20 to 50 percent of the overall construction costs (20 for a general office, 50 for something like an operation theatre); yet the amount spent on designing/engineering the services is not an equal share of the overall design costs. Often the services are the first part of the design to be targeted if cost savings are to be realised. Typically, when a consultant is invited to start working on a project, the fee is agreed in advance, based on the UKs standard conditions as defined by the Association of Consulting Engineers; this leaves little room to conduct simulation work, let alone purchase and train on any new software.

Time is another definitive factor for the context in which consultancy work takes place. It was pointed out that, while consultancy work goes on, the client is often paying interest on money borrowed for the construction process, or not receiving any rent. This puts strong constraints on the room allowed for simulation.

Quality of the building is the main factor that is seen to benefit from the use of simulation. A paramount concern in today's buildings is the prevention of overheating, and to a lesser extent energy saving. Other than that, simulation is seen to be beneficial if it can help to highlight / demonstrate / prove unique selling points (USPs).

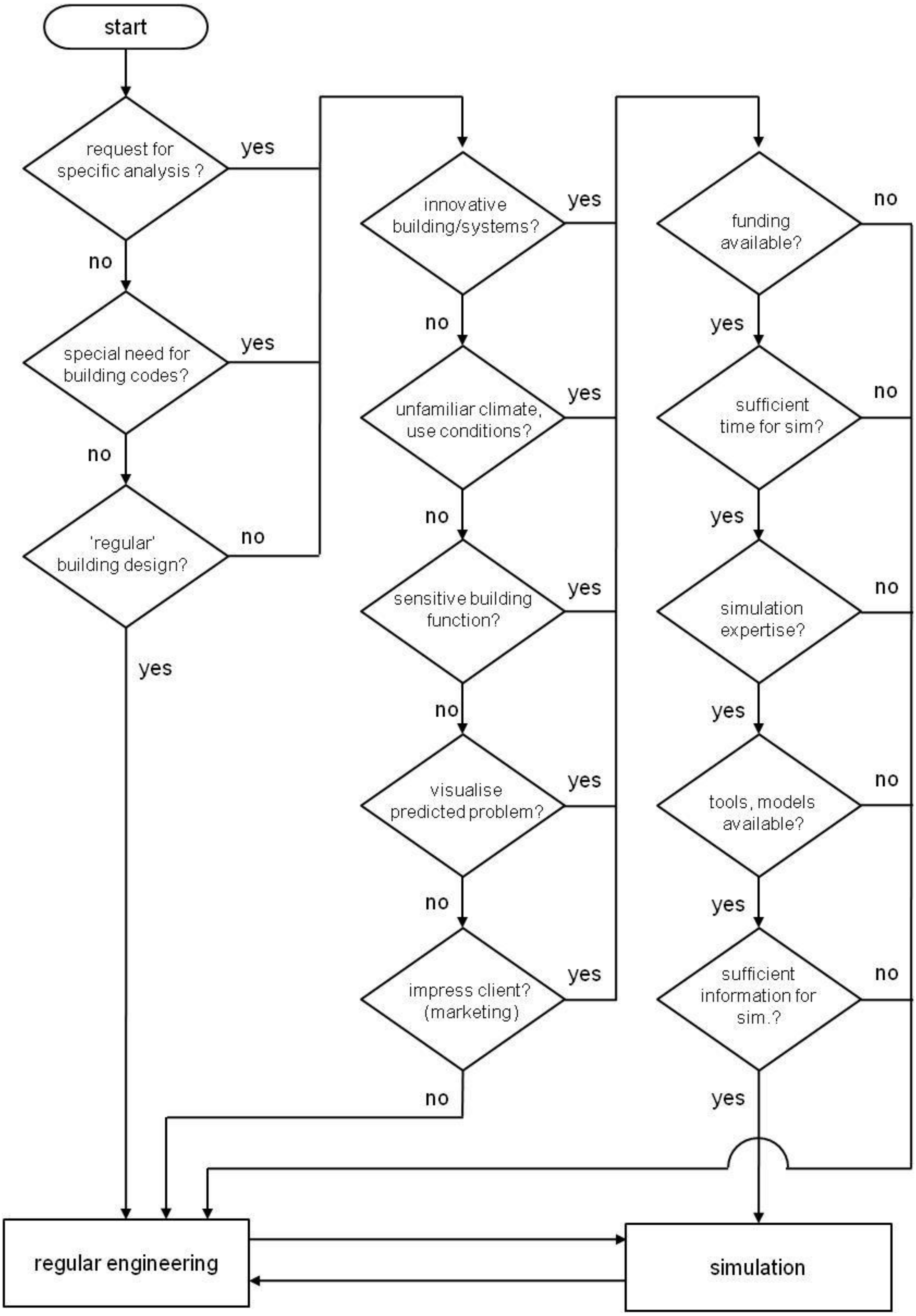


*Figure 2: deployment/non-deployment flowchart*
*for the use of simulation tools in the building design and engineering process*

## CONCLUSIONS AND REMARKS

This project reviews the current situation in M&E (services) engineering in the United Kingdom considering the use of simulation in the building design and engineering process. Based on a questionnaire and in-depth interviews amongst practitioners, the following conclusions have been drawn:

1. Simulation is used almost exclusively in the more extensive projects, in the category of more than £ 20 million.
2. Practitioners strongly rely on their experience and understanding; they prefer simulation results that can be verified. There is some reluctance to outcomes that cannot be checked by a 'common-sense approach'.
3. The information gained from the deployment of simulation tools might be less essential for the design process than many researchers in building science believe; there are a lot of repetitive projects were proven systems can be rolled out, based on experience of the consultants involved.
4. In some cases simulation does clearly add value, especially where it comes to gaining special status like BREEAM excellent ratings, or demonstrate sustainability to a concerned client.
5. The main driver currently is to achieve compliance with set standards, for example the British Building Regulations Part L or energy performance certification.

The flowchart developed in this paper brings together and groups the factors that decide the deployment of simulation in M&E practice. The flowchart can be used as an overview of factors that need to be addressed if the uptake of simulation in practice is to be improved. However, it must be noted:

- Some of these barriers to the use of simulation lie outside the realm of tool development and/or software engineering; addressing these will require interdisciplinary research that blends ongoing technological efforts in the field of building simulation R&D with design process management.
- In any case, simulation is only one instrument available to the building design team, and as such application of tools only makes sense if doing so adds value to the process/product.

## FUTURE WORK

Further work will focus on studying in more depth the actual instances where simulation indeed contributes to the design process. This will be then used to complement earlier work on 'analysis functions', as defined by Augenbroe et al (2004) in the Design Analysis Interface (DAI) Initiative, providing an empirical base for recurring simulation tasks.

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