“An investigation of the use of Building Energy and Environmental Modelling in practice”

A dissertation presented in fulfillment of the requirements for the degree of Master of Science Energy Systems and the Environment

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Bruce F. Elrick

Reg. No 200186473

Faculty of Engineering

Department of Mechanical Engineering

University of Strathclyde

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Abstract

To date, IBPSA (the International Building Performance Simulation Association) Scotland, also known as Scottish Energy Systems Group (SESG), has focused on identifying barriers to the use of Building Energy and Environmental Modelling (BEEM) tools in practice and developing procedures to assist engineering and modelling specialists. This has now reached a stage whereby, through ongoing industry interaction, the debate is taking a step forward, as practitioners begin to use simulation in earnest [Hand and McElroy 2003].

This study aimed to consider how the use of BEEM in practice is viewed externally, how the BEEM is actually being used in practice and provide guidance as to how BEEM could be better used in the future. The key findings of the study are that whilst in the past the use of BEEM in practice had been at best ad hoc a more concerted effort has been made by industry to formulate a more structured approach to its implementation. In-house Quality Assurance has been developed by Hulley & Kirkwood Consulting Engineers Ltd (H&K), whose work is considered through Case Studies within, to ensure this. Documents developed by H&K are presented to help promote more widespread uniformity across the industry with respect to the use of BEEM tools.

CHAPTER 1

Introduction

The use of building energy and environmental modelling (BEEM) in the design of buildings is accelerating at an ever increasing pace. Former research and development software tools are now becoming commonplace in the search for more energy efficient buildings.

Traditionally, there has been a perception that building energy and environmental simulation is difficult to apply in practice, with numerous contributing factors. Much work has already been accomplished by IBPSA Scotland and others to tackle these factors: the steep learning curve, poor ease of use, fear of user error, discontinuity between program capabilities and the scale and complexity of real buildings, a demanding resource requirement, credibility of predictions, need for specialist computing equipment and, most importantly, the lack of a supportive network [Howrie 1995].

The capabilities of BEEM software tools are on the increase and there is still a huge potential for the deployment of BEEM tools amongst design professionals in the UK. It is imperative that all new users are up-skilled sufficiently to gain as full an understanding as possible of BEEM options as there are still only a limited number of experts. Whilst guidance is improving with respect to the selection and application of suitable software there is little guidance as to how tools should be used in practice and how to manage their use successfully. This is partly due to a lack of general understanding of how and when to use such tools and also is a result of information not being disseminated successfully within the industry.

This thesis attempts to ensure a better understanding of the BEEM process and provide material that can be developed and customized by future BEEM users.

CHAPTER 2

Methodology

The task of informing the design of building form, fabric and building services is increasingly being facilitated by the use of BEEM software tools. Many aspects must be considered during their use as, depending on the systems available and the success of the activities undertaken, outcomes can differ widely and not always match the original intent [CIBSE 1998]. One of the key aims of the new Building Regulations in England and Wales, with Scotland due to implement in the near future, is to promote consistency and more towards a greater level of uniformity and standardising of BEEM output. The carbon emission levels of proposed buildings are compared against a normalised building with a view to bringing about savings through the use of better practice construction techniques and new technologies. These changes in building regulations, predominantly with respect to Part L (England and Wales) and Section 6 - Energy (Scotland), encompass the National Calculation Method (NCM) and Simplified Building Energy Model (SBEM/iSBEM), both driven by the European Energy Performance of Buildings Directive (EPBD). These topics are discussed in Chapter 3.

The motivation for this study stems from two main premises:

a) a recognition that recent changes to the Building Regulations in England and Wales has forced the use of BEEM software tools into the design process.

b) an interest in furthering the work of IBPSA Scotland with respect to delivering more successful use of BEEM in industry [McElroy *et al* 2001] and further enabling the management of BEEM software tools within design practices.

The Chartered Institution of Building Services Engineers (CIBSE) published their Application Manual AM11 in 1998 to provide guidance on the selection and use of Building Energy and Environmental Modelling (BEEM) software. The document aimed to provide much-needed information and guidance in this area, whilst providing an opportunity to disseminate this information to the design team as a whole. It offered guidance on the appropriate application of BEEM software, to promote good practice and to offer reference material to all [CIBSE 1998]. The overall aims of the manual were to:

a) ‘raise the awareness of building services engineers, architects and clients to the capability of energy and environmental software’;
b) ‘give a brief, but practically sufficient, account of most of the issues of importance in the selection of such software for those who wish to establish in-house modelling capability’;
c) ‘give practical guidance to users of BEEM software tools to carry out the modelling in an appropriate way with due regard to quality assurance’ [Bartholomew *et al* 1997].

This study aims to revisit AM11 and reconsider it following recent changes to the Building Regulations and the increased use of BEEM software tools across the industry. In particular it aims to consider the recommended infrastructure for effective use of these tools to carry out routine simulation work, in line with simulation activities as described in AM11 [CIBSE 1998]. It will also examine how BEEM use could be more successful within practice. The objectives for this study are thus;

- to identify the current state of the art with respect to BEEM: what are the driving forces for its use within design practices;
- to describe how use of BEEM in practice is viewed externally;
- to review BEEM case studies with respect to the design process;
- to provide material that can be developed and customized by future BEEM users;
- to give guidance on how to undertake future BEEM studies.

The use of the case studies within the company Hulley & Kirkwood Ltd was employed to facilitate the analysis of the BEEM process, in an attempt to make the process more efficient and transparent. It highlights some of the issues faced by engineering and modelling specialists in the construction industry and highlights areas where improvement can be made.

Research for this study and the case studies were undertaken as part of a Knowledge Transfer Partnerships (KTP) project under its former title - Teaching

Company Scheme (TCS). KTP is a Department of Trade and Industry initiative to strengthen the competitiveness and wealth creation of the UK by the stimulation of innovation in business through collaborative partnerships with the UK knowledge base.

The academic partner was the University of Strathclyde, who provided support through the Energy Systems Research Unit (ESRU) and the SESG. The industrial partner in the programme, Hulley & Kirkwood Consulting Engineers Ltd (H&K), provided the test bed for the research project. H&K, currently have offices throughout the UK, specifically, Glasgow (head office), Edinburgh, Aberdeen, Birmingham, Bristol, Manchester, London Piccadilly and Epsom. The practice participated in two, two year TCS programmes in partnership with the University of Strathclyde, with the aim of developing their existing “gateway working” practice and consolidating an in-house BEEM simulation capability.

H&K have been adopting “gateway working” between their various offices for a number of years: this refers to the activity of executing a project remotely from the office where it originated. Projects would typically be controlled via a lead office with help provided by a support office. Unification of the design process and effective communication are seen as the keys to effective “gateway working”. Similarly H&K have been utilising BEEM software tools and undertaking simulation projects for over ten years with varying degrees of success. The inception of the KTP project aimed to consolidate the considerable work already achieved by numerous individuals within the company and provide access to BEEM services across the company. Having a simulation capability on a company wide level allows regional offices to offer simulation based design advice within the design process.

The following chapters address each of the objectives in turn. Firstly the current drivers for the increased use of BEEM in practice are identified. Secondly, a description of how recent literature suggests BEEM should be applied in practice is given. Thirdly, an insight as to how modelling is being used in practice by a firm of consulting engineers will be provided. This is achieved by examining a number of case studies, and reviewing them in line with simulation activities laid out in AM11. This review leads to a better understanding of the BEEM process and provides base material which can be customized by future users to help aid the use of BEEM in practice.

CHAPTER 3

Background

The history and development of BEEM software tools and modelling procedures has been well documented [Clarke 2001]. This chapter aims to review some of the more recent drivers impacting the use of BEEM software tools in practice.

The most significant and wide ranging change to the use of BEEM in practice is the recent revisions to legislation and Building Regulations across the UK aimed at tackling climate change and improving energy efficiency.

In the UK on 15 March 2006 the Department for Communities and Local Government (DCLG), formerly the Office of the Deputy Prime Minister (ODPM), published a news release, citing revisions to the Building Regulations aimed at increasing energy efficiency standards for new buildings. These revisions partially implemented the EU Energy Performance of Buildings Directive (EPBD) [ODPM Circular 03/2006].

These improved new standards came into effect on 6 April 2006 in England and Wales and affected all new buildings and existing buildings where renovation and/or refurbishment are to be carried out. Despite their recent introduction these improved standards will help ensure that developers and/or builders make greater use of energy saving measures to ensure compliance. 'Measures such as increased insulation, more efficient boilers and the consideration of using Low or Zero Carbon Systems such as solar panels and mini-wind turbines' have been cited as key areas for consideration [ODPM].

What is EPBD?

The European Union (EU) European Energy Performance of Buildings Directive was published on 4 January 2003 and required Member States to transpose its requirements into national law by 04 January 2006. The majority of the requirements were to be implemented by the January date, but extensions of time were allowed with respect to some certification and inspection criterion.

The effects of the Directive were widespread and changes in practice for the owners, operators and developers of all buildings in Europe (both domestic and non-domestic) ensued. The Directive aimed to help deliver incremental changes in buildings-related energy efficiency. The key provisions of the Directive were to ensure:

- 'minimum requirements for the energy performance of all new buildings';
- 'minimum requirements for the energy performance of large existing buildings subject to major renovation';
- 'energy certification of all buildings (with frequently visited buildings providing public services being required to prominently display the energy certificate)';
- 'regular mandatory inspection of boilers and air conditioning systems in buildings' [EPBD]

In order to advise the UK Government on the energy performance of buildings and the implementation of the EPBD the Directive Implementation Advisory Group (DIAG) was established.

What is DIAG?

The Directive Implementation Advisory Group (DIAG) was established to advise the UK Government as to how best to address the regulatory requirements of the EPBD. The aims of the DIAG were as follows [DIAG 2006].

- ‘to clarify the requirements of the EU Energy Performance of Buildings Directive and to highlight any ambiguities concerning the Directive’;
- ‘to provide guidance on possible clarifications and their implications when working with the Directive on building energy performance’;
- ‘to establish and support working groups to address specific aspects of implementing the Directive on the energy performance of buildings’;
- ‘to ensure that the Government receives robust and comprehensive guidance concerning the detailed implementation of the European Energy Performance of Buildings Directive and its implications’ [DIAG 2006].

It soon became apparent that new procedures and methods would be required within the existing Building Regulations to help implement the directive.

What is NCM?

The National Calculation Method was the primary method developed for the DCLG to help implement the EPBD. The National Calculation Methodology for the EPBD was defined in the DCLG consultation document on the energy-related parts of the Building Regulations and the Energy Performance of Buildings Directive, issued in July 2004 [ODPM Consultation 2004]. The consultation process itself was a contentious issue with many differing views being offered from all sectors. The NCM uses standard datasets for construction materials, operating conditions and building service information. Using a BEEM computer model, compliance is demonstrated by calculating the annual energy use for a proposed building design and comparing it with the energy use of an equivalent notional building.

Full understanding of the NCM is presently reserved only for those within government as a formal guide has yet to be published, due September 2006. The proposed 'National Calculation Methodology for determining the energy performance of buildings' document should help clarify the calculation methods and how the comparison of design and notional buildings is conducted [RIBA 2006]. The document should allow a more comprehensive understanding of the NCM by defining the full procedure for calculating the annual energy use for a proposed building.

A new simplified tool based on a set of CEN [CEN] standards has been developed to carry out the actual calculation required by the NCM. That tool has been developed for DCLG by the Building Research Establishment (BRE) and is called the Simplified Building Energy Model (SBEM) and is accompanied by a basic user interface - iSBEM. In conjunction with the SBEM tool the DCLG also acknowledge that the calculation can also be conducted using accredited BEEM simulation software. All approved software tools had to comply with regulations as set out in Annex I of ODPM Circular 03/2006 [ODPM Circular 03/2006]. This provided an overview of the criteria for approval and the procedures for commercial software calculation tools to form part of the methodology for the calculation of the energy performance of buildings, such as:

- software applications of SAP 2005 [SAP 2005]
- software interfaces with SBEM; and
- detailed simulation model calculation tools (DSMs).

What is SBEM?

SBEM stands for Simplified Building Energy Model. SBEM is a computer program developed by the BRE to provide an analysis of a building's energy consumption. SBEM calculates monthly energy use and annual carbon dioxide emissions of a building. This calculation is based on a description of the building geometry, construction materials, operating conditions (occupancy, equipment and lighting) and building service information (heating, ventilation and air-conditioning). SBEM makes use of NCM standard databases for construction materials, operating conditions and building service information. iSBEM is the interface tool for the Simplified Building Energy Model developed for DCLG to help meet the requirements of the EPBD.

It was originally based on the Dutch methodology NEN 2916:1998 (Energy Performance of Non-Residential Buildings) and modified to comply with the emerging CEN Standards. As with the NCM there is currently no SBEM user manual to describe all assumptions made by the software.

What is NEN 2916:1998?

The Dutch standard NEN 2916 is a simplified calculation method, and is based on a monthly heat balance approach, it includes estimates for energy use for cooling. Dutch building control, the Consortium of European Building Control (CEBC) have applied it practically for many years, and as a result it was deemed reasonably well-suited to the required task in the UK. During the DCLG consultation process considering proposals for amending Part L of the Building Regulations and Implementing the Energy Performance of Buildings Directive, some technical deficiencies with the existing algorithms were highlighted. Those deficiencies were related to cooling energy consumption and it is uncertain how these were addressed prior to UK application. There were also concerns over its applicability prior to development because the method is based on a monthly heat balance, meaning:

- that it could not assess common UK strategies like night cooling satisfactorily; also,
- it would be difficult for the method to assess the risk of overheating, which by definition, occurs under extreme rather than average conditions.

BEEM software approved for Part L

The SBEM tool has not been without it sceptics, viewed by some as a backwards step in BEEM software tool progress terms. As mentioned previously, in addition to SBEM, other simulation software packages have been approved by DCLG for use in calculating the energy performance of buildings, as required under Regulation 17A of the Building Regulations in Part L2A (England and Wales) They are, currently,:

- IES 'Virtual Environment' software, Version 5.5;
- EDSL TAS Version 9.0.9.
- Hevacomp Version 22

These tools have developed over many decades and much effort has been spent developing user friendly graphical interfaces for these tools. One of the main criticisms with respect to the SBEM tool is that it relies heavily on manual data entry with no graphical representation.

CHAPTER 4

BEEM in Practice

This chapter considers the four main areas identified in AM11 for the effective operation of BEEM software tools in practice [CIBSE 1998];

- Human resources
- Training
- Computing Environment
- Quality Assurance

By considering these four main areas, it can be established how recent literature suggests the use of BEEM should function in practice.

4.1 Human Resources

The success of BEEM studies relies more on the competence of the design team than on the capabilities of the BEEM tool itself. AM11 emphasised the need for greater communication and more cooperation among the design team, in particular to deepen the relationship between architects and building services engineers. It also suggested that a simulation team should typically consist of a team manager and program user, citing two main groups;

a) ‘Partners, managers, or engineers who decide the firm's quality and capability strategies as well as the development of staff resources and training, and who would be responsible for deciding whether or not to use modelling'.

b) 'Engineering and modelling specialists whose day to day job it is to carry out design and modelling' [Bartholomew et al 1997].

As the use of BEEM tools increase within industry its success will lean heavily on the effectiveness of establishing efficient communication between design team members and the creation of better-quality simulation management systems. There is a greater need for initial planning and ongoing supervision is required to ensure successful control of the overall BEEM simulation process.

4.2 Computing Environment

The UK has a strong history in the development of BEEM simulation tools for design of buildings. Commercial systems such as TAS and IES Virtual Environment, and the open source ESP-r system are employed in practice throughout the UK and abroad.

In this respect engineering and modeling specialists are well placed to adopt new methods with respect to the calculation of a buildings energy performance. Increasing numbers of libraries and input data are in circulation having been created both commercially, by software developers, and publicly by the government, in the form of NCM datasets.

4.3 Training

AM11 states there are two main types of training;

- initial training for new program users and;
- continuing professional development (CPD) for program users and team managers.

Formal training is essential to instil accurate working practice from the offset and ensure that all personnel have a satisfactory level of competence before undertaking BEEM studies

4.4 Quality Assurance

It has been suggested that for BEEM to be successful within a commercial company it is essential to have accurate in-house Quality Assurance (QA) procedures [McElroy & Clarke 1999, McElroy 1998].

The reasons for adopting QA procedures for building energy and environmental modelling are many and varied [CIBSE 1998], namely to:

- ‘instil confidence in clients that the work is undertaken to a consistently high standard’;
- ‘estimate the time and cost of consultancy and ensure the achievement of these targets’;
- ‘improve coordination between members of the building simulation team’;
- ‘ensure that the simulation work is addressing the needs of the client’;
- ‘ensure the simulations are accurate’;
- ‘introduce consistency into the implementation of simulations’;
- ‘enable new work to capitalise on previous projects’;

- ‘enable previously archived projects to be resurrected and understood’ [CIBSE 1998].

Table 4.1 helps illustrate the wide range of factors for QA consideration.

Table 4.1: Quality assurance procedures [CIBSE 1998]	
Quality assurance (QA) manager	
	Develop quality statement
	Develop and implement QA procedures
	Operation of QA procedures
	Refining and updating of QA procedures
Simulation team manager	
	Develop performance assessment method documents for commonly occurring problems
	Develop a documentation skeleton of generic simulation strategies and guidelines for adaptation to novel problems
	Develop skeleton documents for reporting results to clients
	Produce documents to record ad hoc modifications to ongoing simulation work
	Establish procedures for archiving documentation on each job and the associated program input and output data
	Check users have followed quality assurance check lists
	Identify the need for new staff or staff training
	Recommend acquisition of new software or computing resources
Program user	
	Develop and maintain standard databases
	Develop and maintain archives of simulation input and output
	Adopt standard file and model attribute naming conventions
	Back-up the computer system
	Maintain a log book of common mistakes and solutions to them
	Develop and apply checks to ensure correctness of the simulation results
	Document procedures and databases used in a series of simulations
	Routine testing of new programs against validation datasets
	Recommend any necessary new programs, computers and staff

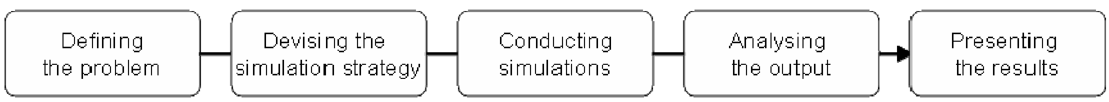
CHAPTER 5

BEEM in Application

In order to examine the performance of Building Energy and Environmental Modelling (BEEM), this chapter considers its practical application and its place in the design process. It considers six case studies all of which are examined using the simulation activities as described in AM11, illustrated in figure 5.1. These five simulation activities represent the key stages of any BEEM study undertaken within the company. Each is treated as a milestone whereby the study can be reviewed prior to embarking on the next stage of the process. Consequently each individual stage is seen as a vital part of the whole process.

All five activities have been tackled and addressed with varying degrees of success of the years and the case studies demonstrate what has been learned with respect to each activity from project to project.

Figure 5.1: Simulation activities [CIBSE 1998]



The six case studies were selected as they cover a large range of building types and illustrate a growth in simulation experience demonstrating how the later case studies are informed by analysis of the earlier ones. This first case study considers a relatively vague thermal modelling assignment for a healthcare project, contrasted with the second study, a well defined site layout residential study. The third case study, a University building, demonstrates the need for a clear brief prior to undertaking BEEM studies; a similar problem is considered in the fourth study, a Primary School. The final two case studies consider the use of BEEM techniques to help understand where existing buildings are not performing as anticipated and help offer solutions to remedy problems experienced.

Each case study is preceded by a brief description of each project and goes on to address the key factors and experiences for each of the five simulation activities. An understanding of how the problem to be addressed in each study is offered along with how the strategy for simulation was devised. This is then followed by a review of how the simulation work was conducted, how the output was analysed and the final results presented.

Findings and comments on the BEEM process for each case study are detailed in the following Chapter 6: BEEM in Application – Findings along with general lessons for the five activities.

5.1 Case Study 1

Case Study 1: Healthcare

Project Description

During the bid stage for numerous Local Improvement Finance Trust (LIFT) projects the use of BEEM was employed, partly as a marketing tool to give the bid ‘added’ value. The LIFT projects were in essence one-stop health centres, or “super surgeries” as sometimes known. They aimed to bring together on one site GPs, health visitors, dentists, a pharmacy, a cardiology clinic, X-ray facilities, optometry services, child care resources and a healthy living cafe.

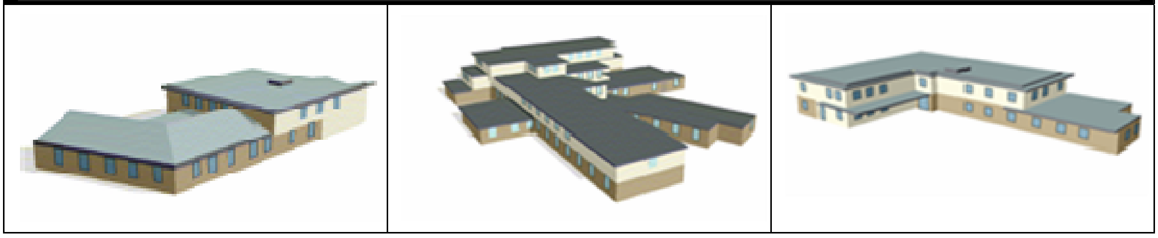
Defining the problem

To support the bid submission indicative results and the production of model images for six LIFT projects were required in a relatively short timescale; as such there was no real brief developed or objectives defined before work was initiated. As all work was to be part of the design team submission the emphasis for deliverables was placed on the visual impact. Images illustrating the affect of the sun with respect to direct solar gain and shading potential were requested, examples of which are shown in figures 5.2 and 5.3. To supplement these, indicative environmental conditions for typical consulting rooms and waiting rooms were also required to help highlight predicated internal temperatures.

Devising the simulation strategy

Architect’s building plans, sections and elevations to help construct the model geometry were provided for use during this study. Due to the project being in its infancy information was limited with respect to building construction and operating conditions. To ensure a useful BEEM study, areas within the building had to be identified for simulation. After discussion with the design team the main zones of concern were selected for analysis. These zones included South and South-West facing Consulting Rooms as well as Waiting Rooms with significant areas of glazing which would provide worst case results. Assumptions with respect to occupants, equipment and lighting were made in line with CIBSE guidance and other best practice documentation.

Figure 5.2: Healthcare Images 1



…/Case Study 1: Healthcare

…/Devising the simulation strategy

With regard to the main zones of concern a sequencing of simulation was agreed to help consider the effects of different ventilation control strategies, see table 5.1 below:

The simulation scenarios typically aimed to demonstrate the importance of user diligence. With window opening scenarios intended to illustrate how failure to comply could result in overheating, especially in naturally ventilated areas where the need to ensure early window opening was highlighted. Diligent use of space also involves users not leaving equipment (computers), heating and lighting switched on all the time.

Table 5.1: Considered Simulation Scenarios	
a)	Windows never open
b)	Windows open after lunch (~13h00)
c)	Windows open first thing in morning (~09h00)
d)	Varying ventilation rates
e)	Varying glazing specification

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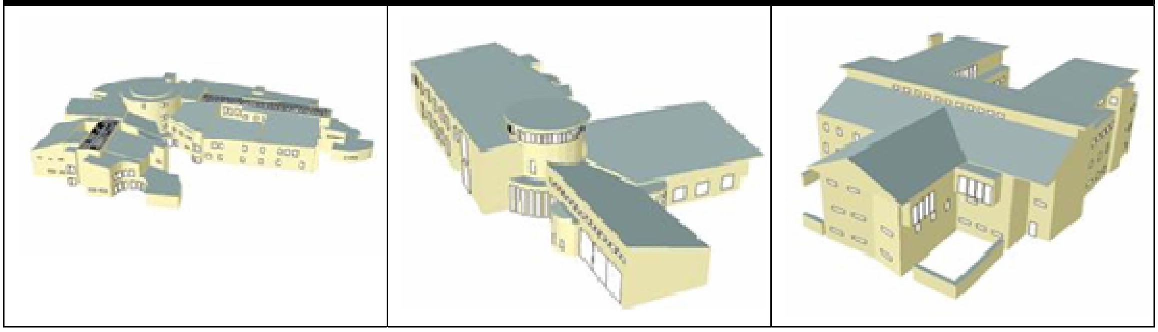
Conducting simulations

Although the BEEM study was only providing indicative results, these results still had to be benchmarked against a known performance indicator to help aid understanding and helped encourage confidence within the design team.

The study was primarily concerned with the possibility of summertime overheating. The design team were keen to employ natural ventilation strategies where possible. Through careful planning supported by the BEEM results it was possible to help reduce the overheating potential without the need for energy intensive cooling.

Figure 5.3: Healthcare Images 2



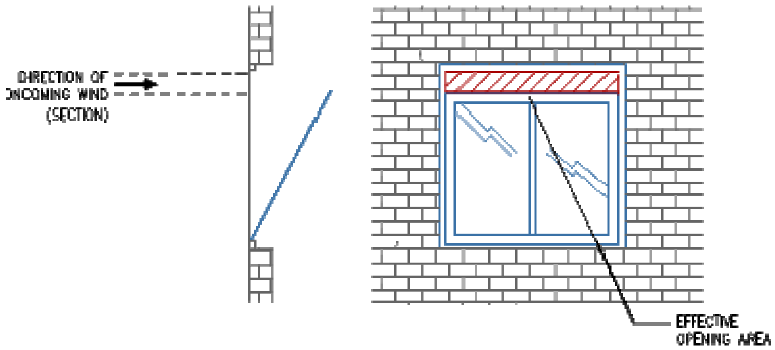
…/Conducting simulations

The simulations were carried out to help check compliance with Health Technical Memorandum 20025 [HTM 2025] which states that where calculations indicate that internal temperatures frequently exceed external shade temperature by more than 3°C, methods of reducing temperature rise should be investigated. It goes on to suggest that options include increasing ventilation rates reducing gains or providing mechanical cooling. This clause infers that room temperature exceeding external ambient temperature by more than 3°C should be minimized. This requirement in itself seems understandable however becomes a little more problematic when considered with Government energy targets of 35-55 GJ/100m^3 in terms of a maximum energy usage meaning that the use of energy intensive cooling must be kept to a minimum. Following the guidance as laid out by HTM 2025 would result in cooling being required in all areas with high heat gains, which in turn makes the Government energy targets more difficult to achieve.

With this in mind maximising the use of natural ventilation was viewed as the best solution to help ensure suitable internal conditions for users whilst meeting Government energy targets. One of the key issues with this and indeed all simulations carried out as part of the study was the difficultly estimating the free window opening areas In determining the effective opening areas of the windows, different factors have to be taken in to account. Pressures resulting in airflow through the window are determined by two driving forces; stack driven pressures (pressure resulting due to thermal stratification) and direct wind driven pressures. The effective opening area of the window is taken as the area of the window that is open perpendicular to the airflow. This is demonstrated for a typical top-hung window below. This would give us a very small area for the case of the top hung window, especially in healthcare and education buildings where openings are limited to an opening distance of 100mm for safety reasons.

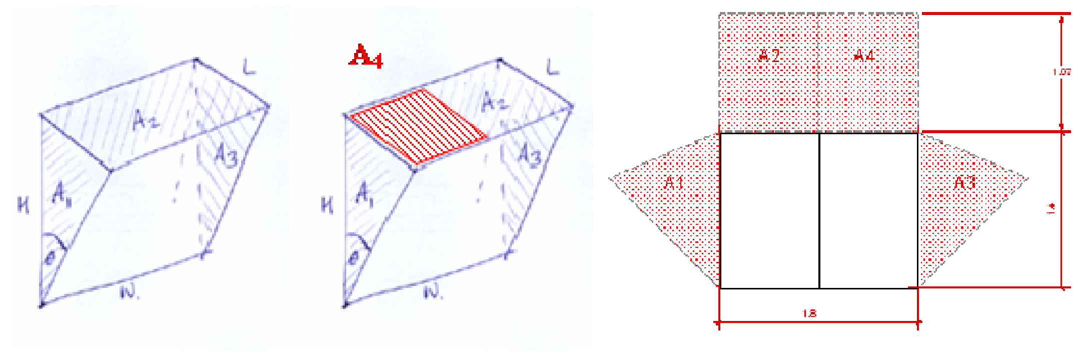
When calculating effective opening areas a relatively complex problem has to be simplified to provide an opening area to conduct calculations on BEEM software with. It is accepted that there are shortcomings in this calculation method, but by approaching the problems in a logical way it is felt that the results will be as representative as possible within the limits of the program, figure 5.4 and 5.5 illustrates the simplification.

Figure 5.4: Effective opening area of a window facing directly into the wind



.../Case Study 1: Healthcare	
.../Conducting simulations	
Additionally different glazing types were considered during the simulation scenarios. Clear solar glass was determined to be the most suitable type of solar glass for two reasons: Firstly, the use of a clear solar glass ensures compliance with clinical functionality compared with tinted glass which can distort patient skin colour and affect the accuracy of other visual observations. Clear solar glass can also be placed only in the rooms where it required without the visual conflict brought about by placing a couple of green tinted windows on an otherwise clear glazed façade, helping to maintain uniformity in elevation treatment.	
Analysing the output	
Much of the analysis concerning the simulation results was spent considering the increase in air flows brought about by the differing window opening strategies into the considered zones / rooms and the subsequent cooling effects as early window opening help reduce overheating.	
Presenting the results	
To help assist the bid submissions all images and results were presented in reports in such a way as to aid understanding by the clients.	

Figure 5.5: Effective opening area calculations



5.2 Case Study 2

Case Study 2: Residential Development 1

Project Description

Local Authorities (LA) are becoming more aware of the issues surrounding site layout planning and are demanding that new designs maximise the use of daylight and sunlight where possible. Consideration of these issues was requested on a recent residential project during the planning consultation process by the Local Authority. This was due in part to the number of objections relating to sunlight and daylight issues, and resulted in the architect being asked to carry out assessments to assess the impact of the proposals on the levels of sunlight and daylight received by the adjacent dwellings and of the sunlight received in gardens of these properties. All assessments were to be compared against the existing situation to help measure the true impact.

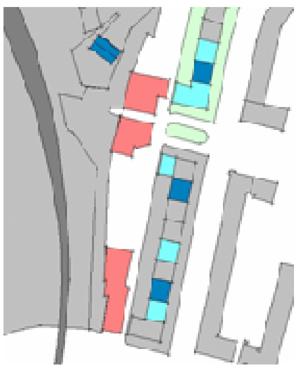
Defining the problem

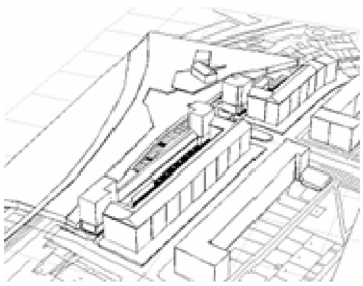
The proposed site itself was for the design of 46 flats, twelve terraced houses and one retail unit, formed by three blocks within an inner urban area. The proposed flats mimicked the existing scale and spatial arrangements of the surrounding tenements. The purpose of the study was to ensure that new development did not adversely affect or impact the existing housing in terms of privacy, overlooking, day lighting or sun lighting. The LA wanted to know that the new buildings had been designed to minimise overshadowing of neighbouring properties.

Devising the simulation strategy

All assessments were carried out in accordance with the LA Development and Regeneration Policies [Glasgow City Council 2001], these specified the different areas to be considered as part of the study based on a British Research Establishment (BRE) document [BRE 1991]. The 'Guide to Good Practice' specified tests for existing buildings, gardens and open spaces to ensure that both the external spaces of existing dwellings adjacent to the proposed development were not compromised and the internal environment for existing residents was not adversely affected.

Figure 5.6: Residential Development Images 1





…/Case Study 2: Residential Development 1	
Conducting simulations	

To help understand both existing and proposed situations, two BEEM models were created, images demonstrating the varying site footprints and massing are shown in figure 5.6 and 5.8, the whole street block was modelled for both situations. The required criterion to be assessed was well prescribed and as such they could be worked through in a logical manner. The study comprised of the tests as laid out in table 5.2.

Table 5.2: Site Layout Planning, Daylight and Sunlight assessment criteria	
Gardens and Open Spaces	Sunlight in gardens and other open spaces between buildings are considered. Recommendations state ‘that no more than two-fifths, and preferably no more than a quarter, of any of the amenity areas should be prevented by buildings from receiving any sunlight at all on 21 March’ [BRE 1991]. Recommendations are a minimum standard and as such compliance would not guarantee large amounts of sun in summer, or any sun during the winter.
Existing Buildings	The BRE document stated that whilst ‘designing a new development or extension to a building, it is important to safeguard the daylight to nearby buildings… The guidelines given... are intended for use with adjoining dwellings and any existing non-domestic buildings where the occupants have a reasonable expectation of daylight... **Availability of Skylight** ‘if none of the obstructing buildings subtends an angle to the horizontal (at the 2m reference height) greater than 25°, then there will still be the potential for good day lighting in the interior”, as shown in figure 5.7. **Availability of Sunlight** Access to sunlight should be checked for the main window of each room which faces within 90° of due south. If this window can receive more than one quarter of annual probable sunlight hours, including at least 5% of annual probable sunlight hours during the winter months between 21 September and 21 March, then the room should still receive enough sunlight.

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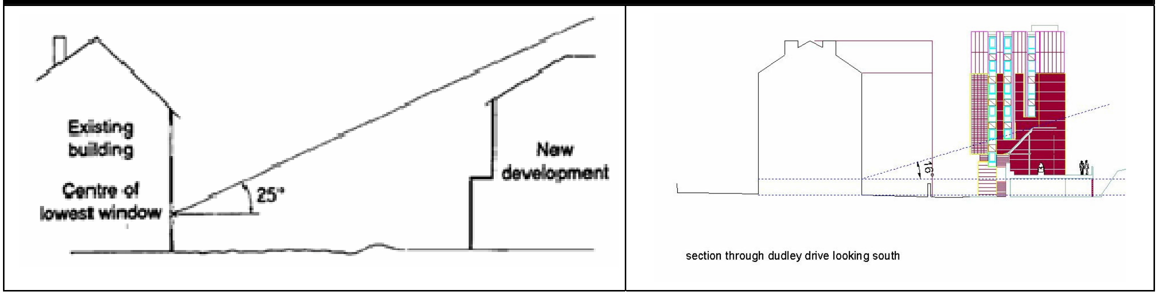
Figure 5.7: Residential Development Images 2



…/Case Study 2: Residential Development 1

Analysing the output

Due to the specific nature of this study, analysis of the output was relatively straight forward. All results had to be considered against the requirements laid out in the BRE document [BRE 1991]. Appreciating the all the requirements were minimum standards the final decision with respect to the overall impact of the proposed development had to be taken by the Local Authority.

Presenting the results

All results were presented without prejudice to be interpreted by the Local Authority. They were provided to help inform both the Local Authority and design team as to the predicted impacts. Depending of what was being assessed, results were presented wither tabular or graphically to best aid understanding. For the Garden Spaces results were shown in a table which detailed how much of each garden (expressed as a percentage) was in direct sunlight throughout the day for the 21st March and 21st June, see table 5.3. Skylight availability was presented using hourly images to demonstrate the overshadowing caused by both the existing and proposed situations for the 21st March. Sunlight availability was calculated using the sunlight availability tool with the BRE document.

Table 5.3 Garden Area Results

March 21st		Area of Gardens in Direct Sunlight (%)						
		< 12h00	12h00	13h00	14h00	15h00	16h00	17h00
No. 33	Existing	0	0	0	0	23	42	0
	Proposed	0	0	0	0	0	0	0
No. 35	Existing	0	0	7	29	97	83	0
	Proposed	0	0	7	29	0	0	0
No. 39	Existing	0	0	67	100	100	100	0
	Proposed	0	0	67	100	60	100	0
No. 45	Existing	0	0	67	100	100	100	100
	Proposed	0	0	67	100	100	83	0

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Figure 5.8: Residential Development Images 3

5.3 Case Study 3

Case Study 3: University Learning Building

Project Description

The proposed University Learning Building had a south facing glazed façade and the design team wanted to examine the potential for overheating within the atrium. Initially an assessment of the shading provision offered by adjacent buildings was carried out; the BEEM model was then used to predict the internal building temperatures depending on various solar-control measures employed. The BEEM project was undertaken to consider various types of solar glass, a series of different blind positioning strategies, and a canopy shade. The aim was to predict the best combinations of the factors above to help inform the design team, so they could reach a satisfactory compromise between environmental conditions and cost.

Defining the problem

The design team had begun to express concern about the overheating potential created by the large south facing glazed atrium, shown in figure 5.9. The design team wanted to consider the additional benefits of the provision of blinds in conjunction with the proposed glazing. Initially the study was to look at a total of five simulations were to undertaken and the findings analysed over the year using the example weather file. The five simulations performed are detailed below in table 5.4. The building was modelled as 16 different zones, the front atrium areas and rear accommodation for each level.

Table 5.4: Considered Simulation Scenarios	
Blind 1*	'Closed Weave' shading blind provision on levels of the atrium.
Blind 2*	'Closed Weave' shading blind provision on levels 3, 5, and 6 of the atrium.
Blind 3*	'Closed Weave' shading blind provision on levels 2, 4, and 6 of the atrium.
Blind 4*	'Closed Weave' shading blind provision on levels 4, 5, and 6 of the atrium.
Blind 5*	'Closed Weave' shading blind provision on levels 2, 3, and 6 of the atrium.
*Includes blinds across the entire roof area of the atrium, whilst blinds were excluded to the east of the stair tower based on the shading assessments study.	

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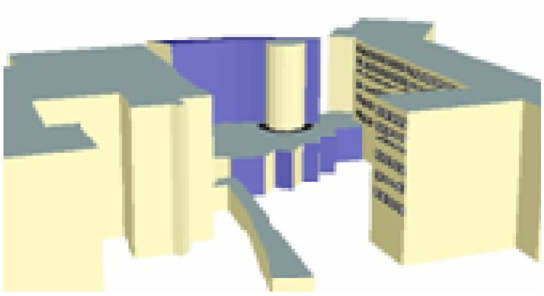
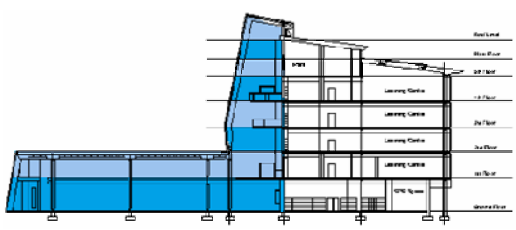
Figure 5.9: University Building Images 1





…/Case Study 3: University Building

Devising the simulation strategy

An initial simulation using the proposed ‘Low E’ glazing system for the atrium glass façade was undertaken. From the five considered simulation scenarios unacceptably high internal temperatures were identified. As a result further simulations were consequently undertaken utilising various measures to better control the environment of the occupied atrium zones, as detailed below in table 5.5.

Table 5.5: Additional factors for consideration	
a)	Solar glass (reduced solar transmittance)
b)	An open weave internal blind (light transmittance levels = 0.58)
c)	A closed weave internal blind (light transmittance levels = 0.17)
d)	A ‘fritted’ glass allowing (light transmittance level = 0.50)

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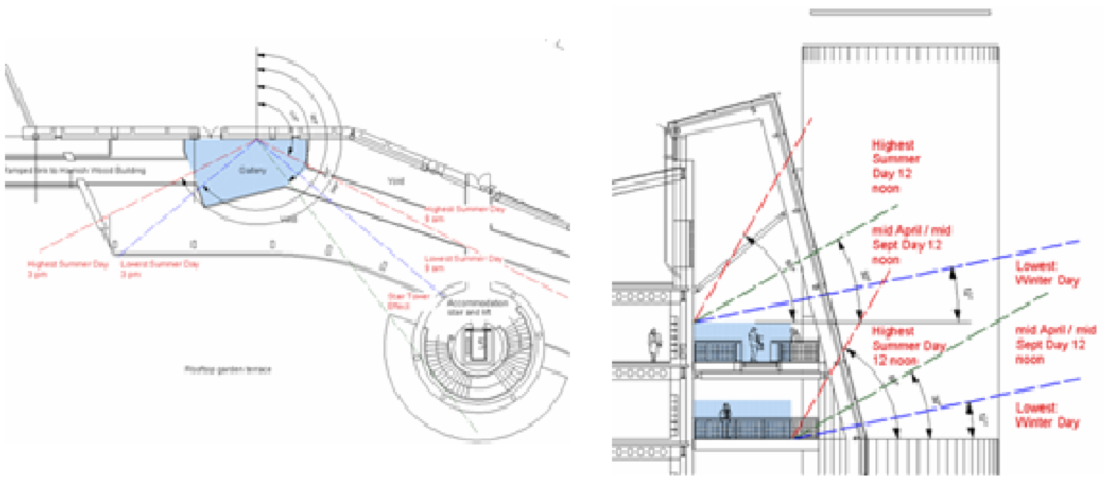
…/Devising the simulation strategy

These additional factors did not provide a conclusive solution and a new strategy began to evolve and a new set of simulation scenarios were outlined, which in turn grew into more simulations until the results delivered a satisfactory answer.

Figure 5.10: University Building Images 2



…/Case Study 3: University Building	
Conducting simulations	

The new set of simulation scenarios are listed below in table 5.6 and continue on following pages;

Table 5.6: Revised Simulation Scenarios	
Base	This was the best performing model from the initial study and served as a point of reference and benchmark for the subsequent scenarios. This simulation had 'Closed Weave' shading blinds provision on the atrium roof glazing and all glazing on the south elevation of the building.
1)	Changes to the original design meant that a comparative model had to e created with three main changes: a reduction in the overall height of the building; changes to the ground floor layout incorporating increased internal gains; re-zoning of model geometry. All of the following simulations continued to use the revised building geometry.
2)	During the design process the building occupancy loads were also revised resulting in reduced bulk air flow volumes. This second simulation incorporated the revised air flow rates alongside the revised building geometry.
To help consider the location for any shading blind provision it was decided to perform further solar analysis to determine where best to locate any proposed blinds on the atrium. Analysis was carried out to determine the solar azimuth and altitude angles to help position and locate the 'Closed Weave' shading blind on the atrium roof glazing and all glazing on the south elevation of the building, see figure 5.10.	

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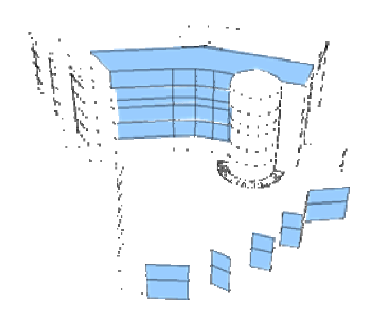
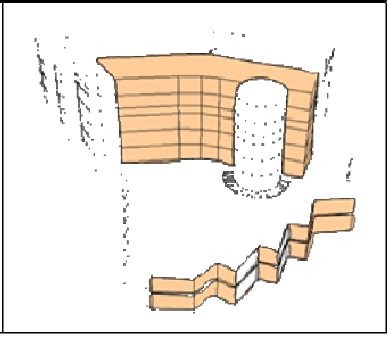
Figure 5.11: University Building Images 3





…/Case Study 3: University Building	
…/Conducting simulations	
Further simulation scenarios, images illustrating model images can be see in figure 5.11;	

Table 5.6: Revised Simulation Scenarios	
3)	The initial solar-engineered option also allows for ‘Closed Weave’ shading blinds to be positioned on the ground and first floor south facing glazing with further blind provision on south facing atrium glazing from the 3rd floor and above.
4)	Due to the level of performance indicated by the solar-engineered solutions it was decided to increase the coverage of the ‘Closed Weave’ shading blind provision to determine the effect on the resultant temperatures within the atrium at third and fourth floor gallery levels. This was referred to as the enhanced solar-engineered option, in addition to the proposed ‘Closed Weave’ shading blind provision detailed in Simulation 3 - solar-engineered, further blinds are also included stretching to the stair tower from the middle of the atrium.
5)	It was noted that the shading provided by the floor plate of the fourth floor gallery was providing a reduction in the resultant temperatures on the third floor gallery. With this in mind it was decided to determine the effects of adding a similar shade above the fourth floor gallery to determine the effect on resultant fourth floor temperatures. This simulation considers a false floor plate (composed of 200mm concrete) over the fourth floor gallery utilising revised air flow rates.
6)	Continuing with the solar-engineered ‘Closed Weave’ shading blinds provision and revised air flow rates, it was decided to investigate the impact of introducing fresh air from outside directly into the atrium to help reduce the resultant temperatures within the atrium. This was simulated in the form of adjustable fresh air inlet louvres on the south elevation atrium glass. These were located at low level on the junction adjacent to the 2nd floor and external roof deck and were simulated in conjunction with high level openings to facilitate stack ventilation during summer periods.
7)	This simulation was almost exactly the same as Simulation 6 but with a timber canopy (10mm thick) replacing the shade above the fourth floor gallery. This model reverts to the revised air flow rates and removes the fresh air inlet louvres used in the last simulation.

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…/Case Study 3: University Building	
…/Conducting simulations	
Further simulation scenarios;	

Table 5.6: Revised Simulation Scenarios	
8)	Again this simulation follows on from Simulation 6 but with a material canopy replacing the false floor plate above the fourth floor gallery. The material canopy stretches across the entire floor with the intention being that any internal canopy could be combined with the atrium feature lighting. Again revised air flow rates are assumed.
In an effort to advance reductions in the fourth floor gallery area it was decided to move away from the idea of trying to position blinds and re-consider the glazing specification to allows for solar control glass. All blind provision on the glass was omitted initially to compare differences in performance. Simulations 9-12 use a tinted (grey) glass.	
9)	This simulation was the first to utilise the solar glass specification detailed above and incorporates a timber canopy (10mm thick) above the fourth floor gallery as in Simulation 7. Again revised air flow rates are assumed
10)	The simulation maintains the same input parameters as Simulation 7. The 'added extra' lies in the fact that the overall area of the timber canopy above the fourth floor gallery has been extended westerly towards the George Moore building to help provide afternoon shading.
11)	Building upon the findings of the last simulation this simulation incorporates the same input parameters as Simulation 10 but it was decided to re-examine the use of adjustable fresh air inlet louvres. In addition to all parameters in Simulation 10 adjustable louvres were again added to the simulation model. It should be noted that the design intent for the building incorporates the provision for night purging. The fresh air intake louvres described above, are ideally located for this purpose and their provision would therefore be ideal for this purpose.
12)	The simulation is exactly the same as Simulation 11 but with the timber canopy removed from above the fourth floor gallery.
Due to the reduced levels of light transmittance brought about by the Pilkington Optifloat Tinted (grey) glass, alternative glass types were consider to examine their impact on the resultant temperatures on the fourth and third floor gallery levels.	

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…/Case Study 3: University Building

…/Conducting simulations

Further simulation scenarios;

Table 5.6: Revised Simulation Scenarios	
13)	This simulation maintains the same input parameters as Simulation 10, with the performance specification of the solar glass altered after review by the architects. A clear solar glass was used which increased the light transmittance levels from 35% up to 61%. Consequently the solar transmittance levels also rose from 40% to 45%.
14)	In view of the results of Simulation 13, the performance specification of the solar glass was further altered to create a 'fritted' glass type material to use in the simulation with 50% of the glass 'opaque' Compared to Simulation 13 for the 'fritted glass' option total light transmittance levels remained around 60% falling from 61% to 58%. At the same time total solar transmittance levels fell from 45% to 40%.
15)	After further discussion it was decided to experiment with different levels of fritted glass across the atrium elevation allowing varying levels of light and solar transmittance into the building.
16)	This simulation further examines the 'grading' of different levels of fritted glass across the atrium elevation. On the 1^{st}, 3^{rd} and 4^{th} floors, glazing with 39% enamel coverage and allowing 64% light transmission was utilised. From the 5^{th} floor upwards including the roof, glazing with 61% enamel coverage and allowing 49% light transmission was utilised.
17)	On ground and first floor glazing a Clear Low 'E' glass was assumed. On the 2nd and 3rd floors glazing with 39% enamel coverage and 64% light transmission was utilised. From the 5th floor upwards including the roof, glazing with 61% enamel coverage and allowing 49% light transmission was utilised. These two types of glass are 'merged' together on the fourth floor level providing a composite of both glass types
18)	This time only the ground floor glazing incorporated the Clear Low 'E' glass, with floors 1-3 using the 39% enamel coverage glazing. From the 5th floor upwards including the roof the 61% enamel coverage glass was utilised. Again the two types of glass are 'merged' together on the fourth floor level.
19)	As simulation 19 but with the timber canopy at fourth floor level removed.
20)	As simulation 20 but with the timber canopy at fourth floor level removed.

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…/Case Study 3: University Building	
Analysing the output	

All of the options explored demonstrate a marked improvement in the dry resultant temperatures with the closed weave blind performing the best, followed by solar glazing, then the fritted glass then the open weave blind. With the exception of the ‘open’ weave blind any of these options brings the predicted dry resultant temperatures to levels that are likely to be acceptable for a transitory space. While the application of the ‘open’ weave blind demonstrates a marked improvement upon the dry resultant temperatures, when compared to the proposed ‘Low E’ glass the temperatures are still unlikely to be acceptable. The design team considered a number of trade-offs to agree on the final solution.

Presenting the results

Twenty different simulation scenarios compared to the initial five anticipated represent a significant change from the actual intent of the BEEM study. The simulation results demonstrate that reasonable levels of comfort may be maintained within the atrium by incorporating the requirements seen in table 5.7, below. These were displayed in tabular format to the client as part of a report.

Table 5.7: Simulation requirements	
i)	Solar glazing applied to the atrium roof and southern elevation of the building.
ii)	Fresh air inlet louvres at the south elevation at upper ground floor level with associated high level openings to facilitate stack ventilation during summer periods.
iii)	A shading canopy over the fourth floor gallery area.

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5.4 Case Study 4

Case Study 4: Primary School	
Project Description	
The BEEM study was undertaken to consider the building performance in accordance with Building Bulletin 87 (BB87). The guidelines of BB87 state the allowable degree of overheating – (80 occupied hours above 28°C) and the study examines ventilation strategies to help ensure that suitable environmental conditions are achieved.	
Defining the problem	
The Primary School was modelled as two separate models, model images can be seen in figures 5.12, 5.13 and 5.14: Classroom block model and Main Hall model which also included the multi-use hall, kitchen, library and staffroom. This BEEM model was used to predict the anticipated environmental conditions within typical ground and first floor classrooms, the hall, library, staffroom and upper corridor areas of the school. To help facilitate natural ventilation of the classrooms passive stacks were used in every class room and hall areas penetrating every level (1000mm x 500m stack) and protruding 1500mm above the roof level, opening grills of area 1000mm x 500mm were assumed in every room.	
Devising the simulation strategy	
Within the Primary School the areas listed in table 5.8 below were considered and their potential for overheating investigated.	

Table 5.8: Considered Simulation Areas	
Ground Floor	
1)	Classroom 04
2)	Classroom 05
3)	Hall
First Floor	
4)	Classroom 08
5)	Classroom 13
6)	Corridor / Social Area
7)	Library
8)	Staffroom

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…/Case Study 4: Primary School

…/Devising the simulation strategy

The BEEM software was used to predict the air temperatures within the test areas for the proposed design and operating conditions. Where failure to comply with BB87 occurred the software allowed different simulation scenarios to be tested, allowing operating conditions and where applicable construction materials and free opening areas which differ from those proposed to be considered and reported. The main period of concern was the school summer term as defined in BB87 and the CIBSE Test Reference Year (TRY) was used. Five separate simulations were carried out to illustrate various design options. Their purpose was to demonstrate how the classroom temperatures increase if the windows are not opened first thing in the morning and how this could be alleviated by passive measures, table 5.10 details window opening size assumptions.

Table 5.9: Additional factors for consideration	
Base Case	current design (clear glazing) **morning opening -** windows opened from 09h00 in the morning.
1)	current design (clear glazing) **afternoon opening -** windows opened from 12h00 in the afternoon.
2)	with **solar glazing** added.
3)	with **passive ventilation** added.*
4)	with **solar glazing and passive ventilation** added.*
5)	with **brise-soleil and passive ventilation** added.*
* Although passive ventilation stacks had been modeled it was not activated until now.	

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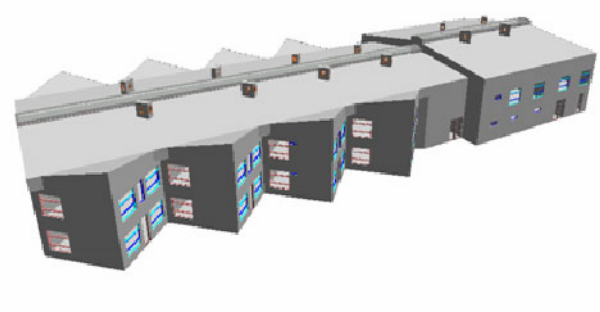
Figure 5.12: Primary School Images 1



.../Case Study 4: Primary School

Conducting simulations

The following table details the window details and opening areas used in the final simulation:

Table 5.10: Assumed aperture sizes

Classrooms	
Glazing Type	Low E glass (clear)
Area of Glazing	11 m^2
Minimum opening free area	3.9 m^2 (both floors)
High level Passivent trickle vents	0.07 m^2 (ground) 0.09 m^2 (first)
Minimum free area of grill into ventilation stack (one grill per classroom)	0.5 m^2
Ventilation stack	
Duct dimensions	1000mm x 500mm
Minimum free area of termination grills (assuming 4 no per turret i.e. one on each face)	0.15 m^2 per face i.e. 0.6 m^2 per stack

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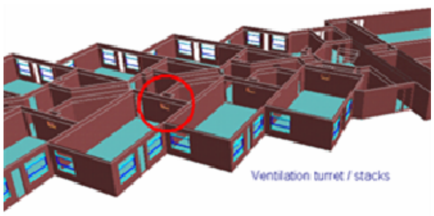
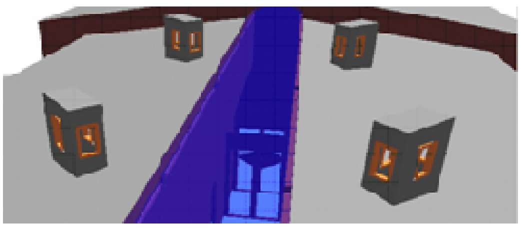
Analysing the output

Before deciding which simulation results to present, the simulation series was performed to determine which classroom reached the highest temperatures over the summer months. The ground floor west facing classroom was the classroom which typically reaches the highest temperatures. This is due in part to a greater amount of solar radiation falling into the room in the afternoon compared to the east facing ground floor classroom which receives only morning radiation. The effectiveness of the ventilation stacks were considered and results presented.

Figure 5.13: Primary School Images 2



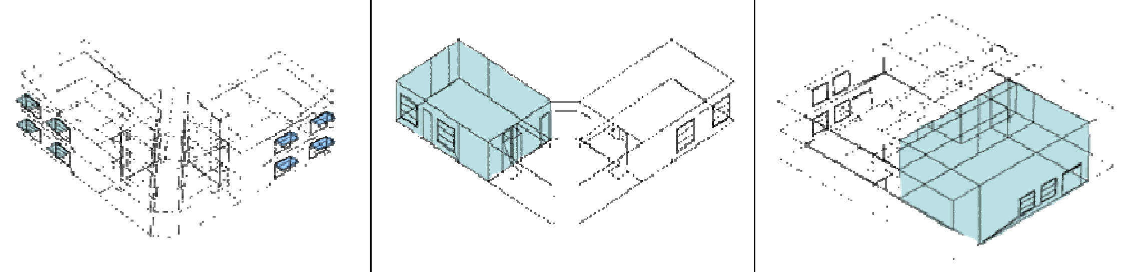


…/Case Study 4: Primary School

Presenting the results

The simulation results showed that it was possible to reduce the number of ‘hits’ above 28°C is below the BB87 limit of 80 hours. Two reports were produced: a full ‘Technical’ report for the design team detailing all simulation findings and results and a shortened ‘Recommendations’ reports for the client and teachers association.

Figure 5.14: Primary School Images 3



5.5 Case Study 5

Case Study 5: Production Plant	
Project Description	
This BEEM study had to assess and appraise the performance of heating and ventilation systems within a Production Plant considering the Production Area, Warehouse and Focus areas. All proposals were to make best use of existing installations and maximise efficient use of energy. The study examined the performance of existing and proposed installations using Computational Fluid Dynamics (CFD) modelling and bulk air flow modelling, to provide a series of proposals, programme and costs. A project briefing meeting was held on site, additionally, a tour of the buildings provided an appreciation of the facility, process and problems experienced.	
Defining the problem	
The model consisted of 24 discrete zones and arranged such that the three key areas of interest, pre-form, auto-build and finishing had the greatest resolution, see figure 5.15. Each zone was attributed with the appropriate construction data and in turn, linked by a flow network facilitating bi-directional flow between each zone. Nodes allowed the ingress and egress of air the conditions of which are determined by the control logic assigned to the PACE air handling units and ambient condition, and then translated into simulation input. During site investigations numerous problems were noted within the production area, other findings are detailed in table 5.11. Within this part of the building there are distinct zones, namely pre-form, auto-build and finishing, had distinct problems with heating and/or ventilation affecting occupant satisfaction, summarised below.	

Table 5.11: Site Investigation Findings	
Pre-form	Small scale vulcanising vessels within this area expel plumes of process vapour discharge into the space, which is extracted via roof mounted fan units. There is no ‘capture’ curtain at the area of this plant and the discharge plume is left to interact with air in the production area.
Auto-build	The main vulcanizing plant is contained within this zone, with the majority of plant machinery enveloped by a curtain/canopy hood, within which are located 15 no. roof extract fan units. The fresh air make-up from either the fan units or louvres is full fresh air, at ambient temperature conditions with no heating, cooling or filtering of air supply. In general terms this zone suffers from high temperatures during the summer months, due to the combination of the radiant heat gain from the plant and ineffective air pattern within the surrounding canopy. Whilst in the winter months the low incoming ambient air causes uncomfortable draughts to the personnel.
Finishing	Due to the quantity of air exhausted from elsewhere within the Production Building, this area suffers from low temperatures especially in the winter period. Other than heat provided by the air handling plant, there is no other significant heat source in this zone. This is exacerbated by wall mounted fresh air inlet units, which contributes to uncomfortable draughts.

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../Case Study 5: Production Plant	
Defining the problem	

The difficulties in overcoming and solving the problems experienced within this area cannot be under-estimated. Solutions which may be applicable and suitable for certain areas may not be ideal for others. For example the introduction of de-stratification fans within the pre-form or finishing area will assist in circulation of warm air from high level, but would not be suitable for the auto-build area where high level extract is not only desired but essential to the operation of the process. The interaction of air flow throughout the building between the various areas had to be considered to allow effective solutions to be developed.

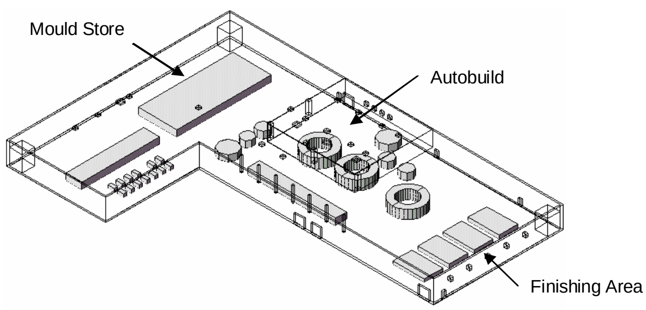
Devising the simulation strategy

The thermal performance of the factory operates between two environmental extremes varying on several variables. In order to quantify these extremes with respect to any given scenario, a series of thermal models were commissioned using numerous BEEM software tools; Thermal Analysis Software (TAS), Environmental Systems Performance (ESP-r) and Fluent CFD software. The combination of each model yields a complete picture as to how the building performed and validates the effectiveness of any proposed HVAC solution.

The accuracy of the model and hence the validity of the proposals were governed by the assumptions made and the resolution of the geometry. From the drawings supplied the geometry could be accurately determined and assumptions were made on the internal gains, based on production figures and site measurements.

In conjunction with the above, all internal gains were attributed in their respective radiant, convective and latent entities. The production equipment forms the majority of gain to the space and, for completeness, lighting, occupancy and additional casual gains were included, all assumed at standard CIBSE figures. Surface temperatures were measured using an infra red thermometer, steam consumption rates and hence latent discharge volumes were assumed the frequency of which based on production lines cure cycle spreadsheet.

Figure 5.15: Production Images 1



../Case Study 5: Production Plant	
Conducting simulations	

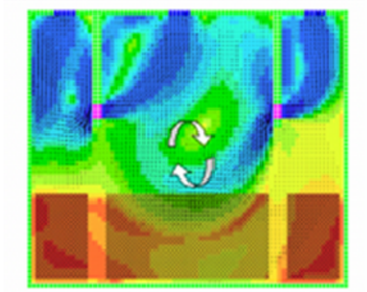
By definition, any bulk fluid model assumes that each zone has a uniform temperature profile. As indicated earlier, it was apparent that uniform mixing within the factory was not taking place. In order to establish the extent of any stagnation, a simple two dimensional CFD profile was employed using TAS. This highlighted the radiant effects of the auto-build and shows the failure of any fresh air to penetrate the thermal boundary layer. Also demonstrated was the high degree of cross ventilation between the incoming air and the roof mounted extract fans. It was determined that the incoming air was subject to a buoyant underlying laminar boundary layer and the effects of the high level extract system. The resulting effect was very little circulation below the point of induction and levels of short-circuiting were demonstrated via the TAS CFD simulation, shown below on figure 5.16. In fact, the interaction of the supply air and process discharge plumes results in a degree of recirculation, all of which not only serves to maintain a high air temperature but compromises the efficiency of the extract system and hence the air quality. By using CFD in this way, the air flow profiles within the bulk fluid model were altered to reflect the short circuiting.

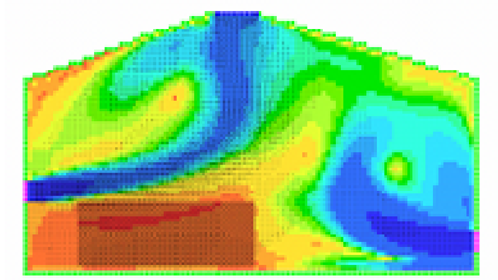
Analysing the output

The resulting graphs predicted a dry bulb temperature range between 10°C (within the pre-form, during the winter case) and 30°C within the auto-build. Internal and external air temperatures were measured on site, the readings matched those generated by the model. Furthermore, discussions with staff appeared to confirm the simulation results were indicative of environmental conditions within the factory. On this basis, the assumptions made were deemed accurate and validation of the model complete with respect to existing installation.

Having established the steady state conditions, a detailed investigation was setup to further enhance the TAS CFD simulation. Using Fluent version 6.0, a detailed breakdown of the flow velocity, profile and the corresponding thermal response was determined.

Figure 5.16: TAS CFD Images





../Case Study 5: Production Plant

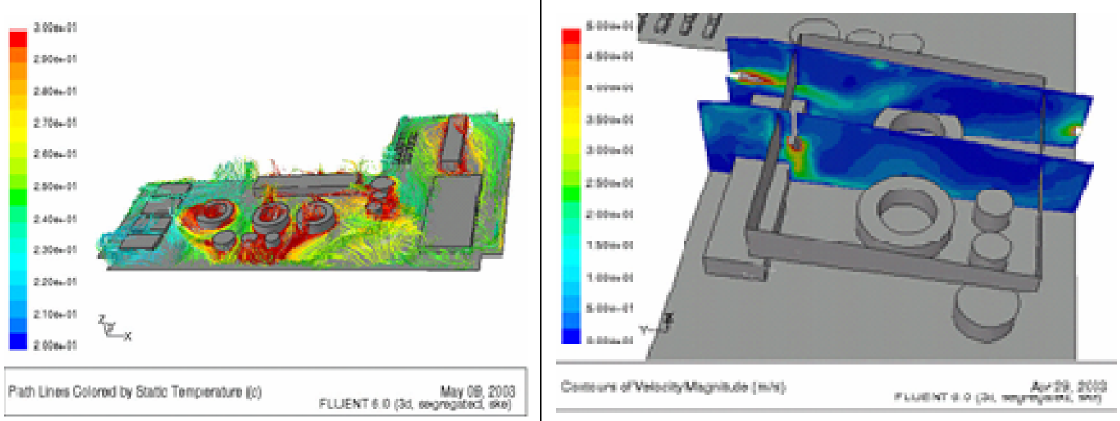
…/Analysing the output

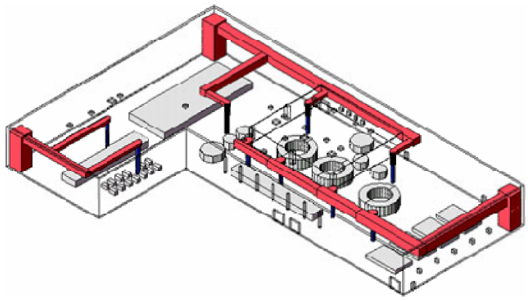
The resulting graphs predicted a dry bulb temperature range between 10^{o}C (within the pre-form, during the winter case) and 30^{o}C within the auto-build. Internal and external air temperatures were measured on site, the readings matched those generated by the model. Furthermore, discussions with staff appeared to confirm the simulation results were indicative of environmental conditions within the factory. On this basis, the assumptions made were deemed accurate and validation of the model complete with respect to existing installation. Having established the steady state conditions, a detailed investigation was setup to further enhance the TAS CFD simulation. Using Fluent version 6.0, a detailed breakdown of the flow velocity, profile and the corresponding thermal response was determined. It was also highlighted that the roof mounted extract fans were only extracting have the stated air volumes due to broken and inefficient fans. By comparison with the Fluent simulation detailed for the existing case the benefits of the corrected roof mounted extract were highlighted not only in the overall distribution of air but the much improved continuity of the thermal environment, images shown in figure 5.17 illustrate some of the CFD images. From the preceding simulation work, it was obvious that HVAC proposals should be developed around the solution of providing the correct volumes of supply air at the correct temperature at low level using the displacement ventilation.

Presenting the results

Three final options were presented varying in capital expenditure with each providing differing levels of enhancement to the working environment. The costs associated with maintenance and disruption caused by existing system deficiencies are also a factor had to be considered in any option appraisal.

Figure 5.17: Fluent CFD Images

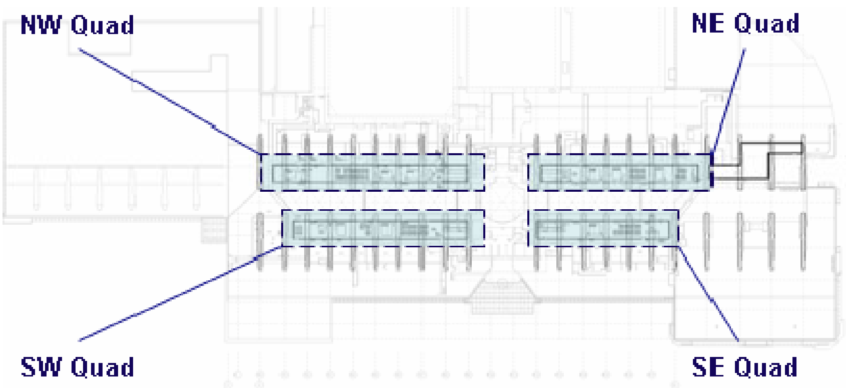


../Case Study 5: Production Plant	
Figure 5.18 illustrates one of the proposed solutions for introducing ventilation at low level.	
Figure 5.18: Proposed Solution	
	

5.6 Case Study 6

Case Study 6: Shopping Centre	
Project Description	
This study focussed on the Tenants central plant installation on NE, SE, SW and NW roof quads of a Shopping Centre, see figure 5.19 below. The purpose of the study was to investigate the current problems being experienced with the condenser water and lack of performance being cited by tenants. Historically, complaints from tenants had been at a high level, but the number of complaints had reduced to occasions of high ambient temperature conditions.	
Defining the problem	
The study aimed to provide feasible solutions that would allow the condenser water system to operate as per the original requirements that is water flow temperature of 29°C to system, with 36°C return at an ambient temperature of 25°C dry bulb. Simulation results which would indicate the adverse impact of locating the dry coolers at low level within the plant well. The study would establish peak dry bulb temperatures within each Quad and determine the frequency of these to establish how often that Quad temperatures rose in excess of the dry cooler working temperature (design ambient temperature) of the dry cooler. The four quad areas modelled are shown below; it was decided to focus the BEEM study upon the areas highlighted, mainly as these areas featured the highest density of dry coolers. In simulation terms, this would provide sufficient information to help ascertain predicted dry bulb temperatures and environmental conditions experienced within the space as a whole. As part of the programme of works regarding the Tenants central plant remedial works, there were numerous visits to site. The purposes of these were twofold; firstly, to conduct surveys of each of the four Quads, and secondly to record environmental conditions for set days to help calibrate the simulation model.	

Figure 5.19: Shopping Centre Images 1



…/Case Study 6: Shopping Centre

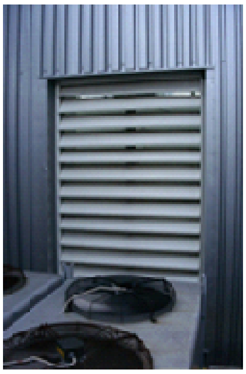
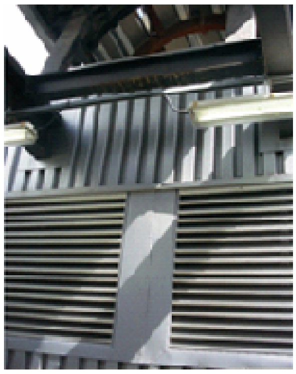
Devising the simulation strategy

Quad surveys were carried out on each of the four plant well areas. These surveys detailed the overall dimensions of the Quads themselves and recorded construction types of wall cladding and floor slabs. Within the Quads, all significant openings, vents and louvres were also recorded. Additionally the location, dimensions, reference types of all equipment located within the Quad was noted to help build up the simulation model in full, see figure 5.20. On the days that measurements were taken in the Quads, typically the temperature differences between outside ambient and plant well ambient temperatures were in the region of 4°C to 7°C depending on operating conditions.

The main plant dry air coolers units provide condenser water for tenants use, are located within the four plant well areas. Each dry cooler has a capacity of 37kW, in the simulation model it was assumed that as the condenser water is cooled by the 37kW, the equivalent kW of heat was rejected into the upper levels of the Quads by the dry cooler fans. The dry coolers located within the Quads have been designed to operate at a design ambient (dry bulb) air temperature of 25°C. The purpose of the simulation study was to establish how many hours in the year the Quads temperatures could rise above this figure and quantify the associated inefficiencies.

The initial simulation considered the environmental conditions within the Quad assuming that no equipment was operating, the temperatures inside the Quads peaked above 25°C for around 60 hours of the year, demonstrating that the temperatures within the Quad sit above the ambient (dry bulb) air temperature. This is due in part to the Quad (shape, layout, wall cladding material and orientation), the exhaust heat from the mall (through pressure relief), dry coolers construction material, etc. If we also consider the impact of all plant operating 24/7, 365 days a year (37kW per dry cooler unit) the predicted average Quad temperature could be as much as 13°C above outside ambient, with average Quad temperatures peaking above 25°C for approx 1000 hours of the year, this figure represented the theoretical worst case.

Figure 5.20: Quad Images

		
Mall side pressure relief louvres over dry coolers	AHU units within Quads	Supply/extract grills on Quad wall sides adjacent to service corridors

…/Case Study 6: Shopping Centre

Conducting simulations

The SW Quad has a total of 24 dry coolers, these sit in two separate sets of 18 units and 6 units. The simulation model concentrated on the area of 18 dry cooler units. For simulation purposes the 18 dry cooler units were paired together to form 9 dry cooler zones, with the equivalent dimensions of 2 adjacent dry cooler units, with a combined heat gain and associated air flow associated to each zone, see figure 5.21 below.

The equipment manufacturer confirmed that the performance/output of the dry cooler drops from 37kW to 13.7kW when the ambient temperature condition rises from +25°C to +32°C, as shown in table 5.12. The simulation results confirmed that when an external ambient condition of +25°C is attained, the quad plant well temperature is actually +32°C. This is obviously out with the design parameter and selection criteria of the dry cooler. The simulation results indicate that the radiation effect of the cladding does not significantly affect the performance of the dry coolers, nor does the glycol content of the system. (Dry cooler manufacturer advising that reducing the glycol content from 25% to 0% would provide an increase in dry cooler output/efficiency by only 3%). The ambient temperature condition within the plant well is the single significant contributory factor in relation to the dry cooler performance.

Table 5.12: Dry Cooler Assumptions

Dry Cooler Rating	Assumed heat gain per dry cooler unit
Plant Well Idle (No Equipment on)	0kW
Dry Coolers – Full Capacity	37kW
Dry Coolers – 83% Capacity	30.8kW
Dry Coolers – 55% Capacity	20.5kW
Dry Coolers – 37% Capacity	13.7kW

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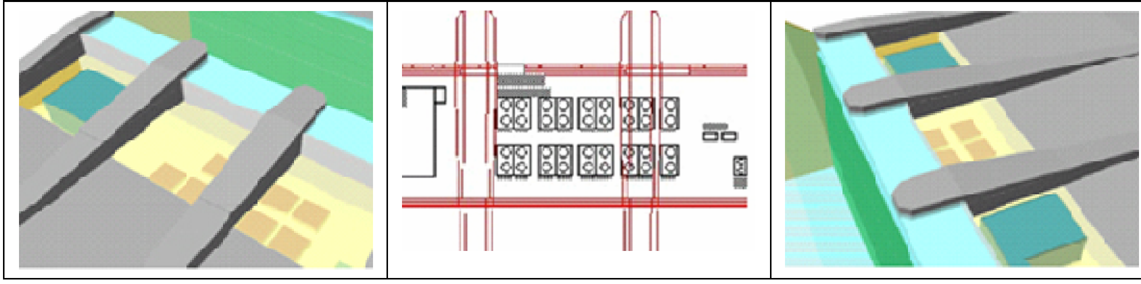
Figure 5.21: Quad Images



…/Case Study 6: Shopping Centre

Analysing the output

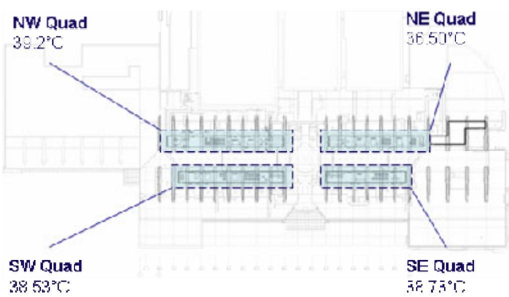
The dry coolers were designed to an ambient temperature of 25°C, the thermal analysis was keen to examine whether this design temperature would be exceeded within the Quads, and if so how often temperatures could be expected to go above this temperature. If the design temperature is exceeded within the Quads then the dry coolers will have a reduced cooling capacity (de-rated duty) depending on the severity of this temperature difference. The figures above indicate theoretical peak temperatures within each Quad for Day 227, assuming that 100% of the cooling capacity (37kW per dry cooler) is rejected as heat into the Quad. This second simulation scenario assumes that the dry coolers are running at full cooling capacity 24 hours a day, 365 days a year. Table 5.13 below details the predicted annual number of hours the environmental conditions within all four Quads will reach set temperatures. This capacity (37kW) is the rated duty for a Quad ambient temperature of 25°C.

Table 5.13: Quad Temperatures

	Quad (annual number of hours above)			
	NE	SE	SW	NW
band (C)				
Total	8760	8760	8760	8760
15	3456	3886	3852	3994
16	3032	3521	3474	3627
17	2574	3154	3109	3277
18	2221	2835	2784	2980
19	1947	2484	2413	2673
20	1747	2171	2126	2322
21	1523	1922	1885	2046
22	1296	1735	1700	1841
23	1085	1520	1483	1638
24	864	1302	1257	1425
25	671	1092	1055	1205
26	509	877	826	997
27	345	680	645	778
28	232	517	485	608
29	153	354	329	440
30	111	241	221	298

.

Figure 5.22: Quad Images



…/Case Study 6: Shopping Centre	
Presenting the results	

Assuming that the Dry Coolers were running on full capacity 24 hours a day, 365 days a year, temperatures within the Quad spaces could rise well above the stated operating temperature for the dry cooler units.

As part of the overall simulation process a simplified Computational Fluid Dynamics (CFD) study was carried out on the quad areas. Computational Fluid Dynamic software analyses external airflow over and around buildings to determine wind velocity and air temperature at any given point in time (provides a snapshot of conditions at a set point). This was carried out to determine, and illustrate graphically, the level of air short circuiting that could occur in the quad areas, see figure 5.23. Short circuiting may occur as the coolers a set in a 4m deep plant well and some of the heat rejected as exhaust air by the dry coolers may not be drawn fully out of the Quad, resulting in some of the exhaust air being drawn back into the dry cooler inlet. Table 5.14 describes some of the proposed solutions.

Table 5.14: Possible Solutions	
Option A	Introduce water spray (adiabatic) cooling facility as retrofit to retained existing dry coolers, and adding further adiabatic dry coolers in each plant well as necessary to meet the duty required.
Option B	Create new plant deck above existing, with new dry cooler with minimum footprint such that top of dry cooler is in line with top edge of roof.
Option C	Create new plant deck above existing, and relocate existing plant such that top of dry cooler is in line with top edge of roof.

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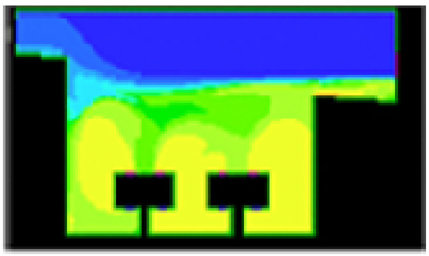
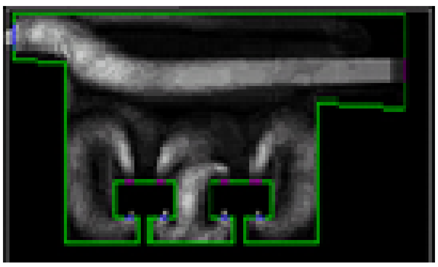
Figure 5.23: TAS CFD Images





CHAPTER 6

BEEM in Application – Findings

6.1 Defining the problem

For those with little BEEM experience, initiating simulation projects and identifying objectives can be at best misguided. ‘As most design team members are not (yet) proficient modellers’ [McElroy and Clarke, 1999], there can be a tendency to rush the initial process in an eagerness to obtain a working “model”.

The case studies demonstrated that undertaking BEEM studies without an initial brief frequently caused problems. In Case Study 1 no initial brief was defined, and resulted in confusion between team managers expectations and deliverables produced by program user. The lack of brief in Case Study 4 resulted in the BEEM model being built twice, as the scope of the project was extended during the design process which meant that areas omitted from the BEEM model had to be included in the analysis. Case Study 3 had a well defined problem but there was no control measure put in place to limit the number of simulation runs.

Whilst it is understood that pressures on the design team can result in team managers forcing program users to initiate early BEEM simulation, without a full brief, there needs to be a process put in place to help prevent abortive work being undertaken. The case studies demonstrated that if program users rush into the BEEM process initial expectations are not satisfied due to lack of communication prior to work commencing. Without proper guidance, program users can spend unnecessary time modelling unessential parts of the building, often at the expense of more importance areas of the building which may not be modelled in sufficient detail as a result. This was demonstrated most obviously in Case Study 4 where the BEEM computer model had to be created twice and the final model later extended to include additional areas for analysis.

H&K developed a simPreStart document, see figure 6.1 to establish and record the purpose of the simulation exercise and to convey this to the client in order that a model can be developed at an appropriate level of detail. This helped forced managers to better consider the nature of all BEEM requests. The simPreStart document helped avoid a repeat of situations highlighted by the case studies where BEEM simulations were undertaken without any real consideration as to the nature of the problem, or indeed what the simulation is expected to prove or disprove. By forcing requests for simulation to be better considered with respect to simulation purpose, time periods of concern, zones of concern, simulation users will become able from the offset to better direct the time. Again it is accepted that in any such system, procedures can be by-passed, and that no system is fool proof, but the intention is to train simulation users to insist upon completion of all such documentation prior to embarking on building a model.

Figure 6.1: simPreStart

hulleySIM

Simulation Briefing Meeting Checklist

Project	....	**Completed by**	....
Project No	....	**Date**	....
Section	________________	**File Ref.**	....
Lead Office (LO)	________________	**Support Office (SO)**	....
LO Key Contact	________________	**SO Key Contact**	....

Problem Definition	✓	**Notes**	**Actions**
Simulation purpose: • What is the nature of simulation work? - compliance checking - environmental conditions - daylight	❑		
Project history discussed: • Design team structure and politics. • Timescales / fees • Envisaged problems, uncertainties	❑		
Building geometry: • Building type / function. • Orientation / degrees from North • Project Drawings - plans - elevations - sections • Operating Conditions - room data sheets • Agree on Climate Data	❑		
Project brief discussed and issued to SO.	❑		

Simulation Tasks	✓	**Notes**	**Actions**
Strategy: • Agree level of model abstraction. (assess zones to be included / omitted)	❑		
• Identify main simulation variables. – aperture areas – construction materials – operating conditions • Identify areas of building to be examined. (number of zones)	❑		
• Agree tasks / scenarios to be undertaken. (number of simulations)	❑		
Schedule review date of preSIM report.	❑		

Specifics	✓	**Notes**	**Actions**
• Fee Agreed	❑		
• Project Drawings Location	❑		
• Agreed Climate File (weather data)	❑		
• Number of Simulations	❑		
• Other information	❑		

The comparative success of Case Study 2, as a result of the simPreStart document, highlighted the benefits of a well defined brief albeit defined in part by Local Authority guidelines. The simPreStart document was also utilized in Case Studies 5 and 6 and helped plan logical studies and ensured all parties involved in the BEEM study were more confident that outcome would better match original intent.

As Case Studies 5 and 6 were existing buildings there was the opportunity to calibrate the BEEM model input data against real life data, this is not often the case. Normally there are many decisions which have to be made relating to construction materials, internal heat gains (occupants, lighting and equipment), HVAC strategies with respect to model input data. Depending on the stage of the design process such information may be, but often is not, available. This has to be 'translated into assumptions based on the collective experience of the modeller and the design team' [Macdonald et al 1999].

H&K have tried to introduce a number of documents to help ensure a more transparent understanding of the assumptions made during BEEM model attribution. The company uses a suite of BEEM simulation programs and it is important the any new procedures and documents are holistic; the first document the simRFI, see figure 6.2, is a simple progression of an Engineers Request For Information (RFI). To ensure accuracy of BEEM studies the simRFI has been created to request information required from the client prior to commencing work.

Figure 6.2: simRFI 1

Simulation Request For Information			
Project Name	Click to add Project Name	Project Number	Number
Simulation Type			
Description			

Request			
Prior to undertaking the above simulation, please provide us with the information detailed in the following table. The documents requested are required before any Building Energy and Environmental Modelling (BEEM) of Click to add Project Name can commence.			
Documents Requested	**Details**	**Provided By**	**Date**
Architects Drawings (Frozen)	DWG's of all plans, elevations and sections including, where possible, the proposed furniture layout		
Room Data Sheets (RDS)	Room data sheets for all rooms within the building.		
Information Requested	**Details**	**Provided By**	**Date**
Simulation Scope	Details of all zones to be considered in study		
Construction Details	Individual building element details for all walls, floors, ceilings, roofs and glazing.		
*** see table on following page for level of detail required for individual building and glazing elements**			
Occupancy Schedules	Details of proposed opening hours and occupancy numbers for each zone.		
Window Details	Details of proposed pening mechanism (top hung, centre pivot, etc) and maximum opening areas, etc.		

Figure 6.2: simRFI 2

Simulation Request For Information			
Project Name	Click to add Project Name	Project Number	Number

* in order to utilize project specific construction and glazing types in any BEEM modelling the following information must be provided all opaque and transparent constructions, feel free to contact the sender for further understanding of these requirements.

Failure to provide project specific construction and glazing types would lead to Building Regulations compliant and/or NCM data being utilized in the simulation which would not reflect any energy efficient constructions utilized in the project.

Opaque constructions		**Transparent constructions**	
Click to add Constuction Name		Click to add Element Name	
Width (mm)		Width (mm)	
Solar Absorptance (%)		Solar Transmittance (%)	
Emissivity (%)		Solar Reflectance (%) - external	
Conductivity (W/m°C)		Solar Reflectance (%) - internal	
Density (kg/m3)		Emissivity (%) - external	
Specific Heat (J/kg°C)		Emissivity (%) - internal	
Vapour Diffusion Factor		Conductivity (W/m°C)	
		Vapour Diffusion Factor	
		Light Transmittance	
		Light Reflectance - external	
		Light Reflectance - internal	
		Vapour Diffusion Factor	
* if no constructions and/or U-values are provided values that comply with the building regulations will be selected		* information for individual panes is preferred required rather than information for double glazed unit.	

* this page can be copy and saved for project construction data

I, the undersigned, have provided Hulley & Kirkwood Ltd with the above information with regards to the Building Energy and Environmental Modelling (BEEM) of Click to add Project Name allowing work to commence on the project. Should any information change following issue I, the undersigned, will provide Hulley & Kirkwood Ltd / hulleySIM with the revised information to prevent further abortive work being undertaken. It is accepted that any changes to the information provided may occur additional fees and lead to subsequent delays cf. the original fee submission.

In instances where some or all of the requested information cannot be provided I, the undersigned, accept that Hulley & Kirkwood Ltd will make suitable assumptions in line with common engineering practice and typical BEEM input.

It follows that the output from the model is only as accurate as the input of the variables associated with the BEEM project. It is essential that all parties understand and accept the various criteria as these ‘drive’ the performance of the building. Where information is not provided by the client, they will be responsible for satisfying themselves as to the accuracy of any assumptions made Hulley & Kirkwood Ltd / hulleySIM.

Name [print]		Company [print]	
Signature		Signature Date	

One of the main problems experienced whilst conducting the Case Studies was the difficulty of managing BEEM assumptions during the process. Current system configuration did not facilitate checking of input and output data within a simulation model with regard to illogical or inaccurate data [Donn 1999]. This made it difficult to 'get up to speed' with simulation projects initiated remotely, which resulted in a reluctance to get involved in someone else's project. Therefore, the development of documentation to make model input data more transparent will play a pivotal role in future BEEM simulation. To help ensure consistency between BEEM projects, H&K established the following folder structure, figure 6.3, to help users move between different simulation projects with a greater understanding of where to find typically required files.

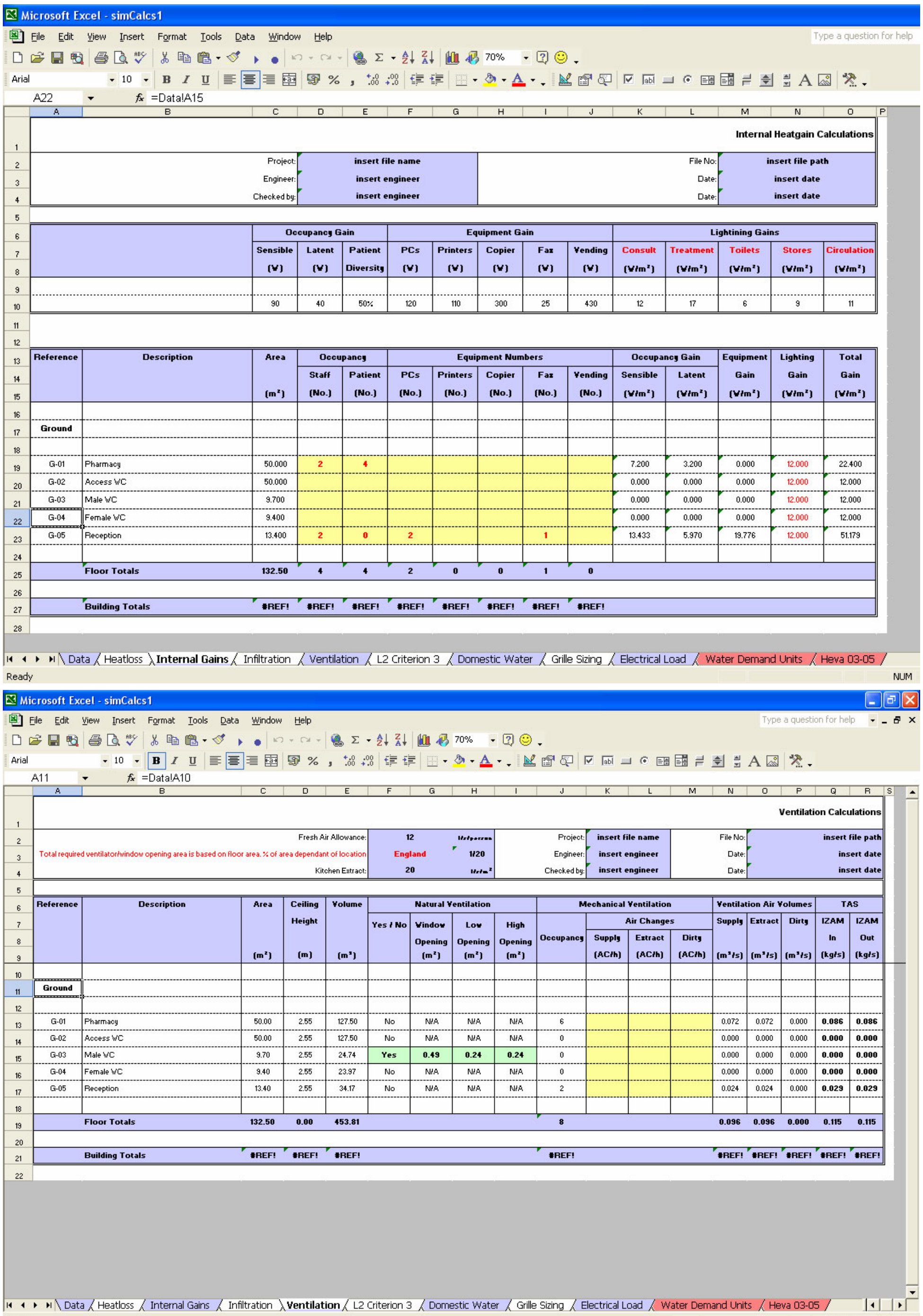
Figure 6.3: simFolder

Name	Size	Type	Date Modified
1_Design Overheating		File Folder	23/08/2006 09:15
2_Criterion 3		File Folder	23/08/2006 09:15
3_Criterion 1		File Folder	23/08/2006 09:15
RGInfo		File Folder	23/08/2006 09:15
simArchive		File Folder	23/08/2006 09:15
simDwgs		File Folder	24/08/2006 09:32
simImages		File Folder	23/08/2006 09:14
simMisc		File Folder	23/08/2006 09:17
simReports		File Folder	23/08/2006 09:14
simResults		File Folder	23/08/2006 09:14
simSandpit		File Folder	23/08/2006 09:17
TAS_databases		File Folder	23/08/2006 15:11
building1.t3d	532 KB	TAS3D Building	23/08/2006 09:15
preSIM_report.doc	945 KB	Microsoft Word Doc...	10/08/2006 12:08
Readme.doc	20 KB	Microsoft Word Doc...	08/08/2006 16:59
simCalcs.xlt	8,245 KB	Microsoft Excel Tem...	11/08/2006 15:32
simLog.xlt	98 KB	Microsoft Excel Tem...	17/08/2006 08:55
simPartL2.xlt	486 KB	Microsoft Excel Tem...	11/08/2006 14:47
simRFI.doc	94 KB	Microsoft Word Doc...	17/08/2006 15:35

With respect to the checking of input and output data the simCalc document, see figure 6.4, evolved from an H&K heat loss design spreadsheet and is viewed as a positive step to removing some of the ambiguity associated with simulation data input. It is envisaged that this should enable users to step in and out of any simulation exercise with far greater ease than is currently the case. It also helps avoid the duplication of data input as this would be detrimental to the overall efficiency of the process.

‘At present there are few quality control systems in existence that allow the simulation user to ensure the relevance and accuracy of their inputs’ [Donn 1999]. More importantly, if data inputs are not accessible it is impossible for a user to grasp their relevance to the simulation project. Again the advent of the new building regulations and more importantly the NCM, has brought about significant improvements in the area, especially with respect to the use of standard datasets for construction materials, operating conditions and building service information.

Figure 6.4: simCalc



Many of the associated problems experienced during the case studies stemmed from the fact that there was no clear guidance as to the requirements of a "model". In practice this often leads to abortive work being undertaken during the already tight design process. The design team can ill afford such profligate use of precious resources and must learn more about the importance of problem definition. Whilst this is now widely accepted amongst engineering and modelling specialists tasked with the BEEM design and modelling project work still has to be done to educate partners, managers, and engineers. Whilst they have a vast amount of technical knowledge related to their discipline, they are still lacking familiarity with the everyday requirements of BEEM tools. The new building regulations are forcing partners, managers, and engineers to better consider the application of BEEM in practice as it has implications both with respect to workload and fees. The requirements of the revised Building Regulations are such that BEEM models will be better defined in order to assess the criteria concerned with;

- Carbon emissions;
- Overheating potential.

6.2 Devising the simulation strategy

Inability to correctly define BEEM problems highlights the need to ensure the modelling strategy has been carefully considered before model construction begins. For that reason it is important to consider the overall level of modelling detail to allow attention to be focussed where it is needed most. It must be agreed which areas of the building are deemed vital to the BEEM study to help meet objectives.

In Case Studies 5 and 6, site visits and discussion with key personnel helped to inform the simulation strategy. However it is more common for BEEM studies to be initiated based on architects drawings with no real understanding of the problem

In Case Study 4 the program user believed that a relatively clear strategy had been developed however changes to the design team lead to the school being re-designed and a breakdown in communication led to classrooms passive stacks being modelled using wrong dimensions.

Ineffective management of Case Study 3 at manager level left modelling specialist producing simulation after simulation resulting in significant changes to simulation strategy made after initial simulations. As the BEEM study progressed the strategy became more ad hoc.

To help better define simulation strategies H&K use sequence arrays, figure 6.5, to help chart the course of BEEM simulation projects. Here all the simulation parameters are listed in a table and those relevant for each individual simulation are highlighted. Ideally one person, not the modelling specialist, should have responsibility for primary strategic decisions. This person need not be directly involved in the simulation process, as long as they are able to direct the modeller so that the objectives of the exercise remain in focus.

Due to the iterative nature of simulation it may be feasible to allow some development stages to go undocumented as the model is evolving. The difficulty is ensuring that sufficient data is stored to ensure that landmark events and changes can be understood by the simulation at a later stage and new-comers to the simulation project.

Figure.6.5: simStrategy

hulleySIM

simSummary

New Summary Form

notes

key (to any abbreviations)

		variable (description or abbreviation)								
ref	**description**	*var 1*	*var 2*	*var 3*	*var 4*	*var 5*	*var 6*	*var 7*	*var 8*	*var 9*
	example	●		●	●					
1		●								
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
10										

For Case Studies 1 and 2 planning the simulation strategy in this way helped agree the nature of the study prior to simulation of the base case.

Before undertaking a BEEM simulation study it is essential that some level of predetermined sequence of simulations has been outlined. This can help avoid unnecessary work once the simulation is off and running as demonstrated in the Case Study 3. The Case Studies, however did demonstrate that even when simulation scenarios have been predefined they can digress from original intent. There has to be a balance between time spent setting up a clear plan of simulations to allow for the base simulation to generate unexpected results, leading to the need for a different strategy plan. Typical issues that could be addressed by the scenarios include changes to;

- air change rates;
- glazing types and areas, opening schedules;
- occupancy, equipment, lighting heat gains;
- heating and cooling controls;
- infiltration, ventilation levels;
- supply air temperatures; and
- lighting controls.

The key factor is to ensure that too many changes are not made at the same time and each step represents a logical progression form the last.

6.3 Conducting simulations

A key problem that has been highlighted by simulation users in industry is the ability to maintain an audit trail once simulations progress beyond the base case model. New and experience users alike find it difficult to track all of the changes made to the original model as it evolves, once the base case model has been created and archived. The ability to track changes as the design is developed is required, ideally within the software tools themselves [McElroy et al 2001].

The simulation study itself can take many forms, as detailed in AM11. The BEEM software tool itself can be used to extrapolate information with respect to construction types or to identify extreme hot and cold days in the weather file. Simulations themselves may vary from simple problems, with an uncomplicated building quickly attributed using standard datasets for construction materials, operating conditions and building service information, which might be simulated for a year and comments given on results, to complex problems, where the building consist of multiple zones and the impact of more detailed simulation strategies explored. Frequently simulations studies consist of sensitivity analysis; where many factors are explored their subsequent effects on the results for the building examined.

Case Studies 1 and 2 showed the benefits of known performance indicators as the helped to benchmark the simulation process against known criteria. Case Study 3 illustrated that when no limitations are put on the overall number of simulations to be conducted the overall process can get out of control. It this instance the whole simulation process began to react to results of last simulation undertaken but with no clear definition of acceptable performance, therefore no logical conclusion. This lack of performance specification brought about modelling uncertainty during the simulation meaning that original deadlines were missed.

Generally conducting the simulations is a relatively straightforward task, it is what happens before and after in the BEEM process that need to be addressed. In the Case Studies 5 and 6 where existing buildings were being examined the simulations helped to highlight potential problems. In both cases problems with the existing situations were identified during the simulation process, i.e. dry coolers expected to function out with their design temperature and faulty roof-mounted extract fans. There is a general desire amongst consulting engineers to increasing post contract assistance in this way to provide feedback for future jobs.

6.4 Analysing the output

'Simulation allows designers to perceive the future reality at the design stage' [McElroy, et al, 2001]. The implications of simulation results have the potential to significantly alter the design of a building. Currently all engineering and modelling specialist do not necessarily have as full an understanding of engineering knowledge as their managers. This fact can serve to act as a QA milestone in itself. This means that there will be a need at some stage in every simulation process for an expert 'advisor' to help with the interpretation of simulation results. This is necessary as simulation users who have been involved in the model creation can find it ‘difficult’ to detach themselves from the process and their judgement with regard to simulation results can become biased.

In this way the results from the Case Studies were able to assess known parameters (temperatures and airflows) and the output assessed in accordance with engineering expertises and expectations. The simulation studies allowed results to be benchmarked against one another to measure % improvement. Engineering decision eventually taken on allowable temperature limits within space.

The analysis process needs to be a two stage to help assess model intent and integrity. Modelling Specialists within H&K relied heavily on this principle to guarantee results were as accurate as possible and frequently an unsullied view the BEEM problem could bring about new perspective with respect to possible problems and solutions. It helps mangers to better understand the simulation process to allow better use of simulation results to inform their design [Donn 1999].

Similarly new users without the benefit of expert ‘advisor’ can find it difficult to know how best to use simulation results. They are unable to determine if the results of their simulations proved whatever the proposed building or system was ‘any good’. Again there is not necessarily an immediate solution to this type of problem. Assuming that users are able to understand the performance impacts of intended design actions it is important that methods for informing clients improve. Clients prefer brief and clear documentation and graphs recommending simulation findings

6.5 Presenting the results

Developing presentation formats suitable for non-expert digestion is a non-trivial task [Soebarto & Williamson 1999]. The presentation format of the Case Studies continually evolved; initially a standard report document had to be created which was improved after feedback from each project. During Case Study 4, the client deemed the initial report too technical and a secondary report with recommendations only had to be produced. Accordingly H&K put a lot of effort into providing user-friendly reports for varying types of BEEM studies, as shown in figure 6.6. There are two levels of report currently employed;

- Technical Reports, documenting full sets of simulation results and supporting literature for thorough examination and;
- Recommendations Reports, typically for general client issue, and providing a brief summary of simulation results and recommendations.

Standardising the way in which simulation results are reported to the client will mean that similar projects could compared and clients themselves would grow to have a better understanding of the process and become more confident about questioning simulation results.

Figure 6.6: simReport contents page

Church Street Southport
New Health Centre

21 July 2006

CONTENTS:

HULLEY and KIRKWOOD

Page 3 of 76

HULLEY SIM

The changes in Building Regulations should bring about new measures to help standardise results as design and notional building emissions rates are compared.

CHAPTER 7

Integration of BEEM into Design Practice

7.1 Human Resources

AM11 stated how it is “unsatisfactory to combine the roles of the team manager and program user”. Program users are concerned with detail while managers consider the broader picture. Accordingly both roles require differing skills. Many engineers appreciate the need for the increased use of BEEM in their offices. In order for this to take place clients and fellow professionals alike need to be made aware as to the possibilities that simulation has to offer. The ability to offer traditionally non-standard design services are becoming a prerequisite for some jobs, services such as;

- BREEAM and EcoHomes [BREEAM] assessments for offices, industrial units, retail developments, schools, hospitals, prisons and homes,
- Standard Assessment Procedure (SAP) [SAP 2005] rating evaluation,
- Site layout planning for daylight and sunlight appraisals.

With such services being requested more readily, there has been a shift within Consulting Engineers to create simulation, sustainability and virtual engineering type groups offering varying levels of services. This has brought BEEM to the forefront of initial design team discussions as the value of such services in securing projects is acknowledged.

What is apparent as the use of BEEM becomes more accepted during the design process is that there is a growing need for the whole design team to sufficiently understand all stages of the BEEM process.

The Case Studies demonstrated that work on BEEM projects is typically undertaken by the graduate Mechanical Engineers, who are increasingly getting exposed to BEEM tools during their undergraduate studies, or other interested Engineers. Currently the use of BEEM software tools is weighted towards mechanical engineers but mainstream simulation packages are beginning to hold great appeal for electrical engineers.

Lack of understanding can be cited as the most common reason for unsuccessful management of BEEM projects. The case studies showed that frequently a manager would commission a BEEM study without appreciating the full nature of the request. This resulted in studies being undertaken with no brief. The recent changes to Building Regulations have forced managers to better understand the BEEM process and requirements.

The case study findings and the introduction of the legislation discussed earlier raise the issue as to the requirement for a new breed of engineer. Is it time for a BEEM Engineer?

7.2 Computing Environment

As BEEM studies are more frequently undertaken there is an increasing opportunity to build up the knowledge base to help inform future work. Reference databases of previous studies can help facilitate future model attribution and past results can help benchmark new output.

Engineering and modelling specialists still find it difficult to regularly maintain standard databases or update them with recently acquired project specific information. Software tools do not readily facilitate the storage of multiple user data and often project specific data resides solely with the engineering and modelling specialists who conducted the initial study. This is seldom made available to help inform future projects as there are often no logical procedures in place to facilitate this.

The benefit of rigour in documenting model assumptions has been the subject of extensive research [Hand 1999]. The current problem is that building energy systems are complex and their design is an iterative process, an understanding of what data to record and not record is critical to success. In practice, however, it is often the case that information regarding data input is at worst held only in the head of the simulation user or, at best consists of randomly recorded sketches and/or data assumptions drafted on pieces of paper, which are inevitably mislaid during the simulation process. This is in conflict with the rigorous and explicit reality of the complex nature of the buildings under examination. Such information must be immediately accessible so that all information can be queried by team manager and/or program users alike.

Ideally a core of simulation constants has to be established that can enable new users to understand the nature of the problem whilst also understanding how it has evolved. At present there are minimal quality control systems that allow the simulation user to ensure the relevance and accuracy of their inputs (Donn, 1999); more importantly if data inputs are not recorded it is impossible for a new user to grasp their relevance to the simulation project.

There is a need for commercial software to provide a greater level of QA information within the BEEM tool, either visually or through the ability to produced standard QA reports detailing model information. Software development could go a long way to solving some of the QA problems typically experienced especially if commercial software logged model changes automatically [Hand, 1999]. In addition to the issues surrounding accuracy, storage and retrieval of data, the management of simulation within design practice is another core issue facing managers [Davies 1999].

7.3 Training

H&K have been supported over the years by the SESG who have assisted with the transfer of computer simulation knowledge and the development of procedures for its application through Supported Technology Deployments (STDs). The use of SESG training opportunities has allowed H&K to develop a basic level of understanding amongst interested staff ensuring the utilisation of BEEM simulation across all offices and disciplines.

Historically, there has been a resistance to the use of BEEM software by design professional due to the associated ‘steep learning curve’. As the need for BEEM studies becomes more widespread the need for individuals to be trained up on specific software tools increases. As well as software training, training should also be encouraged in management techniques to aid understanding of QA procedures. Due to the recent changes in Building Regulations the DCLG has made created a competent persons scheme for practitioners and building professionals. This will allow competent persons to calculate CO_2 emission rates for domestic and non-domestic buildings and undertake the energy rating calculations associated with Part L. This brings about an opportunity to embed sound knowledge in a wide target audience.

7.4 Quality Assurance

Quality Assurance (QA) procedures should provide the overall framework within which successful simulation teams operate. Whilst it is acknowledged that the individual (whether simulation manager and/or program user) should be responsible for assuring the quality of the work which he or she undertakes, this becomes a little less pragmatic if no framework exists.

In larger practices there may be a dedicated quality assurance manager who may be tasked with high level QA, such as ISO 9001, etc. However it is unlikely that there is someone dedicated to the BEEM QA process. The case studies highlighted the problems of not having well defined procedures in place. Many individuals struggled with the same problems in terms of unsatisfactorily management of BEEM projects. It is accepted that individuals all have varying standards of work and differing levels of organisational skills, making it imperative to help regulate and simplify the BEEM process where possible. The important factor is that successful QA management procedures should be possible even for those with little BEEM experience.

QA involves documenting aspects of the BEEM work; the extent of the documentation is the crucial issue within a commercial environment with the degree of documentation depending on the size and nature of the project. As well as project size variations in timescales, available information, input data requirements, output formats, need for legislative compliance and associated risk should all be expected. Accordingly it is important that QA procedures must be flexible enough for these project by project variations without resulting in new procedures and/or methodologies having to be created for every new BEEM project. The procedures can be most valuable if they focus on those aspects of simulation work that vary little between projects. The primary concern within industry is ensuring that QA procedures do not impede the flow of the BEEM study.

In order for QA procedures to be effective, it is important that they are established in collaboration with the all group members. If group members are given a platform to share their own experiences (positive and negative) and ‘rules of thumb’, the resulting QA procedures will be deemed to be applicable to all and are more likely to be viewed as being helpful to the process. Within H&K a user group had been established to discuss issues and develop procedures. The key factor to ensure successful gateway working is to ensure that models can be transferred effectively between users.

CHAPTER 8

Conclusions

Two core issues facing simulation users are the management of simulation and the quality assurance of related models and appraisal results [McElroy and Clarke, 1999]. BEEM modelling is becoming embedded within the existing design process, in the same way it is now equally important that QA becomes embedded in the BEEM process.

The Case Studies demonstrated that whilst improvements have been made with respect to the use of BEEM in practice, there needs to be greater widespread developments made to ensure further success for the industry as a whole. More concrete efforts with respect to successful management of BEEM studies will help avoid some of the painful lessons learned from the Case Studies as a result of poorly defined BEEM problems.

The satisfaction experienced from the execution of well defined BEEM projects, has justified the effort by H&K to improve their overall process. In Case Study 2 this additional work was vindicated as the architect involved was so pleased with the deliverables that a good working relationship was established and further studies undertaken

It has been shown that H&K have developed their own documents, each termed Modelling Assessment Procedure (MAP), in order to facilitate BEEM simulation management. These serve as means to record standard input information and assumptions required during the simulation process. Previously this information was recorded in pre-defined forms in order to make simulation information more accessible to any member of the design team, and to maintain an audit trail. The issue of the potential for discrepancy between model data and stored model documentation was identified from the outset.

These were met with initial scepticism as much of the MAP's included information typically already detailed elsewhere as part of the traditional Mechanical and Electrical design process. Creation of a BEEM simulation user group meant that these quickly evolved and the most significant progress was brought about when modification to existing engineering documents and datasheets, including 'rules of thumb' and calculations spreadsheets were modified to include BEEM input fields. The following documents are in place within H&K to help;

- ensure that all required input data is available prior to beginning the BEEM study;
- satisfy the client as to the BEEM design intent and modelling assumptions;
- record model changes sufficiently;
- familiarise all users with typical folder structure for BEEM projects;
- notify team manager and/or program user of the assumed input data;
- provide a standard reporting format.

In some cases it has not been possible to show the full documentation; as some, for instance, are over 50 pages in length (simReport) whilst others exist on Microsoft Excel spreadsheets and it is not possible to demonstrate their full capabilities on paper (simCalc). Full copies of any of the documents can be requested from the author.

The introduction of the new Building Regulations has resulted in the use of BEEM tools becoming commonplace with the construction industry and forced companies to better consider the procedures in place to maximise the benefits of these tools. The Case Studies provided an insight into simple measures that helped H&K address some of these deficiencies experienced. It is intended that this work can be developed to further ensure the successful implementation of Building Energy and Environmental Modelling in practice.

Social

The industry is buoyant following the introduction of the new Building Regulations. Whether clients, developers, builders and Building Control will be as content with the recent changes remains to be seen. The changes have brought about the need to increase capital expenditure at the offset of projects to introduce more energy efficient measures. Building Control are having to get to grips with the relatively unwieldy submissions brought about by the new Buildings Regulations. In some cases Building Control are not as familiar with these requirements as they could be due to its hasty introduction.

Fiscal

The government has reacted promptly given the demands of the EPBD and has to be applauded for producing the SBEM in such a short space of time. This study has been mostly concerned with detailed simulation model calculation tools. This has been largely due to H&K existing expertise with use of commercial software tools. As mentioned previously these tools provide the same output as the SBEM. They can also provide answers to other energy and environmental issues such as overheating and daylighting from the one BEEM model. For relatively experienced users the SBEM tools provides a simplified tool to help address the Building Regulation requirements but will also require an investment of time to understand sufficiently.

Recent legislation has brought about a real chance to increase the energy efficiency of the UK building stock. These new measures, alongside changes to strengthen Building Regulations in 2002, will go someway to meeting the target of improved standards by 40% [ODPM Circular 03/2006].

Economic

The economic benefits of the new Building Regulations have already been seen within H&K, with the company getting involved in projects where they are not the appointed Building Services Engineers but are employed to undertake BEEM work. Other consultants are commanding additional fees for BEEM compliance work. Similarly new companies have emerged solely focused on BEEM compliance work. Legislation with respect to building certification and boiler and air conditioning inspections will also bring about further financial rewards for those positioned to accommodate the new requirements.

Although in its formative stages and relatively unproven, the requirements of the new Part L: Conservation of fuel and power (2006 edition) [DCLG, 2006] could generate a significant additional workload. This additional workload will be generated both for Dwellings with revisions to the SAP calculations, and for Buildings other than Dwellings should help consolidate the use of BEEM in practice.

Recommendations for future work

It is intended that the MAP's provided as part of this study act as the catalyst for real and meaningful development of BEEM procedures in practice, in the same way that AM11 did back in 1998. Since AM11, developments associated with BEEM material have not been disseminated at sufficiently regular intervals to maximise impact and further successful use in practice. Whether this has been intentional or not it is hoped that the unveiling of MAP utilised in industry will trigger more parties to share their closely guarded materials. Ultimately it is hoped that any MAP offered as part of this study could be used to develop UK wide standards.

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