EXPERIENCE FROM A DESIGN ADVICE SERVICE USING SIMULATION

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ABSTRACT

The UK Energy Design Advice Scheme (EDAS) is a regionally based independent design advice scheme which is sponsored by the UK Department of Trade and Industry (DTI) through the Building Research Establishment (BRE) to improve communication between design teams and experts in low energy technologies applied to buildings. It delivers advice on all aspects of energy effective building design and refurbishment to architects, engineers, designers and building users.

Over the last eight years, with EDAS support, design studies of several hundred building projects have been undertaken, many involving detailed simulation. These studies have been conducted for a large variety of clients by a number of modelling teams. A current EDAS (Scotland) initiative at the University of Strathclyde seeks to analyse those projects involving simulation modelling, in order to determine if there are common approaches and procedures. If such paradigms can be found, there is then the potential to create templates for some of the more typical questions asked of modellers. This paper reports on the operation of EDAS and on the ways in which EDAS is researching dissemination routes for the delivery of design advice.

INTRODUCTION

The integration of simulation modelling into the building design process is increasing, but is not yet standard practice. Design teams working on 'ordinary' buildings are less likely to make use of modelling software than the designers of prestige or complex buildings. The use of computers in building design tends to be restricted to CAD and steady state calculations, carried out in parallel with other design team activities. Generally, simulation is regarded as expensive and too complex for everyday design problems. In addition, the employment of a full-time specialist simulation modeller within a design practice is often difficult to justify on the grounds of lack of full time (modelling) employment. Where opportunities do exist, there is a recognised risk that the modeller could be restricted to specific tasks rather than bringing a new dimension to the design process. Thus, simulation tends to remain an expertise procured from external sources.

The Energy Design Advice Scheme bridges the existing gap between designers and expert knowledge: providing free and fund-supported advice on all aspects of energy effective building design to design teams and their clients.

Following a three-year pilot study in Scotland, from 1989 - 1992, four EDAS centres were set up in the UK, located in Scotland, in England (London and Sheffield) and in Northern Ireland (Belfast). In addition to in-house staff, who have specialist knowledge of low energy design, each centre retains a list of expert consultants who are commissioned as the need arises: this further consultancy is funded, in part, by the client and in part, by the DTI via EDAS.

DAY TO DAY OPERATION OF EDAS: Design Advice

Government support from the DTI provides EDAS with the means to offer design advice on two levels:

1. Free *Initial Consultation* advice (of up to one day's duration) based on recognised "best practice", supported by simple design tools, accepted design guidelines and exemplars.

2. Subsidised *Full Consultation* advice - if scope for significant energy savings and/or environmental performance improvement in a building is identified, EDAS can support additional analysis. This further work is undertaken by 'expert' consultants registered with the scheme. These in-depth studies of design options allow designers the opportunity to test new design theories at a fraction of the commercial rate. Technical support, for example on the interpretation and application of simulation results is provided by in-house EDAS staff throughout this analysis phase.

Through EDAS, designers can gain access to simulation modelling at a reduced cost, similarly simulation modellers are linked with designers with real design problems, during the exercise, EDAS provides ongoing technical support. By opening up this channel of communication EDAS creates a two-way information flow between these complementary aspects of building design while underwriting the risks perceived by design teams not familiar with the technology. The creation of these links is seen to have a positive influence on the development of the design process and of simulation models as applied to building design.

EDAS MONITORING RESULTS

EDAS has been monitored extensively by an independent research consultant[1]. The following statistics have been established for the 1500 projects analysed over the five years of operation from 1992 - 1997:

Effectiveness - Energy Saved

For every 1 ECU spent on the operation of the national scheme, 10 ECU of equivalent energy saving potential has been identified. This amounts to a potential of around 23 million ECU saved per annum. Feedback from EDAS Clients indicate that of the advice received, an average of 65% is implemented, resulting in a net annual energy saving of 15 million ECU.

Cost of Detailed Analysis

The cost of procuring a detailed study on a project through EDAS has ranged from a few hundred ECU to 25,000 ECU. In order to qualify for a high level of funding, it must be demonstrated that potential energy benefits will justify the level of financial support. Projects which have attracted such assistance tend to be large scale, and involve a degree of design innovation. For example, simulation was employed to analyse internal temperatures in the new British Airways building near London's Heathrow Airport. The project comprises a number of buildings, linked by an internal street and the intention was to avoid mechanical cooling. Dynamic simulation was used to study fabric mass and self shading to optimise plant requirements. The study resulted in plant cost savings of the order of 350,000 ECU.

More typically, for an 'everyday' project, the cost of an EDAS study is of the order of 2,000 - 7,000 ECU. The potential energy and/or environmental benefits are established as part of the initial assessment and this will inform the level of funding offered.

Design Questions Asked

Generally, designers seek advice on a range of issues from heating system selection or insulation levels to integration of renewable energies and effectiveness of complex passive solar features in large commercial buildings.

The analysis of the advice offered indicates that the majority of questions relate to fabric measures (24%); heating systems (19%); ventilation (18%) and fenestration (18%), although it is difficult to draw definitive conclusions as many of the design questions asked are multi-faceted.

It is encouraging to note that a high proportion of projects are brought to EDAS at the feasibility stage (around 49%), when, it is argued, decisions are being made which will have the greatest impact on energy and environmental impact. This is reflected in a similar proportion of new build projects and in the fact that architects are the most frequent users (31%) of the scheme; especially at the early design stage. Local Authorities are the second largest client body, although within this group questions often relate to detailed analysis of existing buildings and refurbishment projects.

Building Types

Buildings are categorised according to the Energy Efficiency in Buildings series, as published by the UK Department of the Environment[2]. The breakdown is shown below:

Offices	18%
Housing	16%
Libraries Museums & Galleries	9%
Higher Education	8%
Sport & Leisure	8%
Factories & Warehouses	7%
Schools	7%
Health Care	6%
Hotels & Multi-Residential	4%
Cinema & Theatre	2%
Other (e.g. Retail)	15%

To date, EDAS has established itself as a valuable source of independent advice on energy related aspects of building design. However, in 1998 the EDAS service in Scotland will have been running for a total of nine years and Government funding will cease. It is expected that by then, EDAS will have achieved its objectives in that the scheme will have raised awareness within the design community of the need to reduce energy use in buildings and that through EDAS, designers will have formed links with 'local experts'. It is recognised that while EDAS still has a role to play in the production of successful low energy designs, it may still be necessary to evolve the scheme in order to remain at the leading edge.

CURRENT EDAS INITIATIVES

1. Dissemination Routes

Over the past eight years, EDAS (Scotland) has provided advice on over 1000 projects. Of these, around 25% have benefited from financial support on dynamic computer modelling studies. The evaluation of these 250 buildings, many of which are now built and occupied, has provided EDAS with a unique data set of design information within the EDAS building archive. A number of in-house initiatives are attempting to translate this information into a format both useful to design professionals and appropriate for dissemination.

In order to address issues such as energy use, environmental impact and sustainability, design teams need access to better design advice. However, the available information is often not suitable for direct application.

Advice is required on:

- Current best practice from sources such as:
  - National Government : e.g. the UK's Best Practice Programme.
  - European Community and International Energy Agency R & D Programmes.

- The application of appropriate new low energy technologies to a specific building.

- Techniques of performance assessment including state-of-the-art computer simulation.

- Optimisation of comfort levels in the internal environment.

Guidelines and Exemplars

In the UK, EDAS is one of the main routes by which the Government disseminates 'Best Practice' information from BRECSU - the Building Research (Establishment) Energy Conservation Support Unit - directly to designers. Thus, EDAS provides design teams with access to the most recent information available from recognised research institutions world-wide. EDAS also provides assistance with the interpretation and application of the information available.

Case Studies

Since 1993, EDAS has been compiling a series of paper-based case studies, outlining the advice provided and benefits accrued on a number of projects. These illustrate the process undergone in involving EDAS on the projects, what tools were employed, how they were used and why. The aim is to highlight the benefits of the service, and to encourage designers to make use of the service available.

Multi-media Database

In order to expand the dissemination routes, and to reach a wider audience, a current initiative is transforming the design advice and performance information generated by EDAS into a hyper-text based repository of case studies (Fig 1) to conflate the achievements from applying good practice principles and state-of-the-art computer simulation at critical stages in the design process. So far, each case study includes specific design questions; information on the nature of assessments undertaken; the resulting performance predictions and the design advice given. The ultimate aim is to produce a fully interrogable, interactive database, built-up in layers of complexity and varying interests, to inform designers and clients about key design issues, features and decisions which affect the energy and environmental performance of buildings. The work includes a review of relevant case study exemplars and information sources.

In order to be of real benefit to designers, the database must be coherent, integrated, and informative. It is therefore considered critical that a common thread exists. For each project the following are identified:

1. Factors considered to be key design issues.
2. Key features - architectural and energy related.
3. Initial analysis indications.
4. Impact of further analysis.
5. Final Decisions.

Fig 1 - Database - Project Introductory Level

At the 'top' level, information held within the database is project specific, it contains project summaries and reports set out in such a way that users can browse similar building types; design issues, climatic information, and so on, in order to identify issues relevant to their own projects (Fig 2). Low energy design principles which were employed are built into each case study as 'hyper_links' which, if selected will lead the enquirer to a different 'layer' of the database (Fig 3). The information contained within this second layer will not be project specific, rather it will provide design information for application on a more general level. At a third level, it is the intention that the database will reveal, for each project, the methodology by which advice was provided, including details of simulations conducted and how this was integrated into the process. For each case study, up to four initial and four detailed level design issues are identified, explained in general terms and analysed in the context of the specific project (Fig 4). Comparisons with exemplars are also made as a reference point. The potential to build-in links to other methods such as simplified design tools or spreadsheets is being explored, as is access to project specific simulation / dynamic analysis 'snap-shots'.

The chosen format for the encapsulation of the data offers the opportunity to add and remove case studies as required. In addition, scope exists to expand the information included for a particular project - by post construction or occupancy re-evaluation for example.

To date, the multi-media database contains around 70 projects, most of which are entered as outline case studies with links to a layer outlining how and why a detailed analysis was conducted, and the aforementioned 'hot words' linking the case studies to more general advice.

Fig 2

Fig 3

Fig 4

2. Simulation Methodology

Analysis of the EDAS case material could also help to identify a methodological approach to the use of simulation as an effective, integral part of the design process. In particular, the development of common approaches to translating design questions asked by building designers or their clients into specific modelling objectives could assist the development of a common language between design professionals and modellers, thus ensuring meaningful answers and predictable results from the application of building simulation.

This is an ongoing objective which is being tackled through case study analysis in the database and by EDAS's involvement in the production of case study material for an Applications Manual for Building Energy and Environmental Modelling [3,4].

Issues being considered include:

1. Identification of *design team objectives*.
2. Typical range of *design questions* asked.
3. How these design questions are translated into specific *modelling objectives*.
4. Common procedures for undertaking simulations (e.g. *input data*;creation of *reference models* against which parametric variations are undertaken; phased studies; iterative procedures; frequency of client/simulation team meetings etc.).
5. *Interpretation of results* and client *reporting requirements*.
6. A description of the final design and how the modelling exercise influenced this.
7. A brief discussion of other issues which could have been investigated by simulation but were not included in the study.

FROM CASE STUDY TO METHODOLOGY

One building in particular has been analysed in some detail: as an EDAS Case Study, as a Multi-media Database entry, Post Occupancy Evaluation study[5] and as a Simulation Case Study within the Applications Manual for Building Energy and Environmental Modelling. The following section of the paper uses this project to develop the issues discussed in the preceding sections, by outlining:

- The nature of the project.
- How it was assessed.
- The methodology employed.
- How this informed the design process.

THE SCOTTISH OFFICE - VICTORIA QUAY, EDINBURGH.

Nature of the Project

EDAS provided design support and advice to the design team on the application of thermal simulation modelling in the evaluation of the a proposed low energy office development for the Scottish Office at Victoria Quay, in Edinburgh, Scotland.

The designers' aim was to avoid air conditioning, and in arriving at an outline design, they had employed recognised low energy design principles for a naturally ventilated and daylit building. Through discussion by the design team, EDAS and the modelling team, it was agreed that thermal simulation would be used to predict the effect of building form, fabric, and glazing distribution on the thermal performance and energy consumption of the proposed building.

Fig 5: Victoria Quay

EDAS worked closely with the design team and the simulation consultants in order to ensure that both teams had at their disposal the most up-to-date design information available from current best practice guidelines and state-of-the-art buildings. In addition, the simulation process was phased over a two year period in such a way that it was possible for EDAS to use this project as a model to explore the procedures involved in building up an understanding between the two teams, which had similar objectives but different perceptions of the 'building'.

Assessment

The strategy consisted of shallow plan office accommodation grouped around central courtyards or atria, although at this stage the nature of these spaces was not defined. Key issues assessed included the potential to exploit natural light and ventilation through building form, the use of the fabric mass as a heat sink and the use of a 'mixed mode' ventilation system whereby the building would be naturally ventilated in summer, but would use mechanical ventilation in winter in order to reduce cold air ingress by reducing the need to open windows.

After discussion, a three-phase approach was planned with initial studies focused on the optimisation of fabric mass and building form in terms of thermal and natural ventilation performance. Attention centred on the configuration of the atria / courtyard designs.

In summary, the questions identified were:

Phase 1: Overall building concept design :

- Can natural ventilation be used to provide fresh air requirements and prevent overheating or is some additional mechanical ventilation required?
- What are the benefits of features such as atria and courtyards in terms of thermal comfort, ventilation performance and energy saving potential?
- What are the peak building and plant loads? When do these occur? and What are the main contributors to the building loads?

To answer these questions the simulation team had to define them in terms of the building model. The questions were translated thus:

- Predict peak summertime temperatures assuming natural ventilation and compare these against a performance target set by the design team.
- Building form study - Compare the thermal and ventilation performance (thermal comfort, overheating risk, energy consumption) of the building with three design variants of the central space (atrium, open courtyard and atrium with north light only) under design winter and summer conditions.

Methodology Employed

Reference Building : For comparative purposes, a reference model of the building with summer and winter operation as initially proposed by the design team was developed. From this, other design variants were created during the course of the study to investigate particular options. Detailed construction information, occupancy details and equipment loads were provided by the design team.

Simulation Database : Other factors addressed were: appropriate climate data; materials information; casual gains; model zoning and boundary conditions. Accurate materials specifications; internal heat gains from people, lighting and equipment; and the proportional split between sensible and latent / radiative and convective heat gains were identified as critical to the prediction of internal temperatures and the optimisation of the design. These were all discussed in detail between the teams and EDAS.

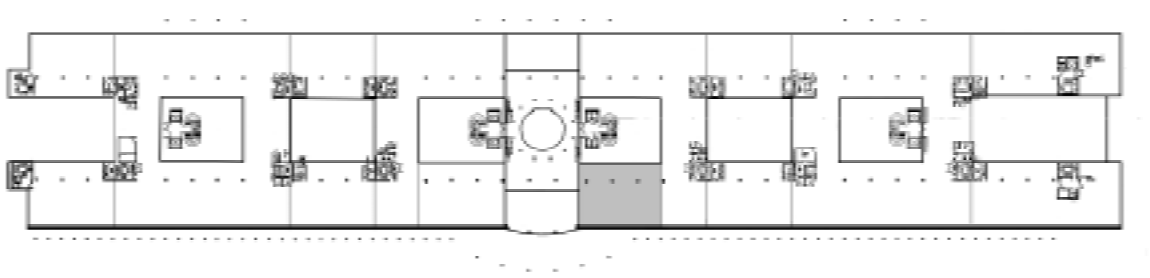


Fig 6 - Victoria Quay - Building Plan

Rather than building a model of the whole building, it was decided to simulate a representative section of the building in detail. A model of a typical courtyard block (see figs 6 & 7) was deemed adequate for extrapolation to the whole building and also would permit more detailed studies of specific issues if required. Zoning strategy was almost self-defined by the physical barriers between office spaces, the outside and the core areas in the building. As the design was open-plan, zones were large, and sub-division was not an issue. Thus, the 35,000 m^2 building was represented by a 22 zone 5,300 m^2 model of a typical building section.

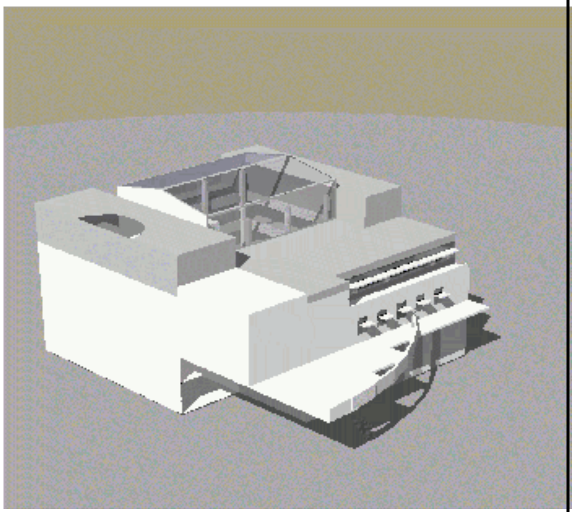


Fig 7 Victoria Quay Model View from South-East

Airflow Study : The teams agreed to simulate one day in summer and one day in winter. For the winter case, the design team proposal was that 2 air changes would be provided by mechanical ventilation. For summer, it was proposed to use natural ventilation, and so an airflow network study was undertaken to predict infiltration rates.

It could be argued that the figures adopted for summer and winter air change rates in this case are of limited value - given that infiltration could be driven by other factors. The predicted summer air change rate was close to the upper level of the 'preferred' range of acceptability as far as both teams were concerned so that discomfort, disturbance of papers, etc., would be limited and occupants would not be tempted to close windows.

Thermal Studies : The 'building' was simulated for extreme summer and winter design day conditions to predict worst case performances for the various courtyard / atrium options, to optimise the ventilation strategy and to assess comfort and overheating within the offices. The control strategy selected was 'ideal', with no cooling in summer and as much heat as required in winter. A time step of one hour was selected on the basis that this would be adequate to show general behavioural trends.

Conclusions : Phase 1

In summer, overnight purging was found to be required to achieve comfort conditions (maximum Resultant temperature of 26^{o}C) and performance objectives during the occupied period in the office areas. Significant benefits in running costs could also be achieved by delaying the introduction of mechanical ventilation until the internal temperature reaches the outside air temperature. The proposed plant system was predicted to maintain most areas of the building at adequate comfort levels during the winter period, and there would be thermal benefits in winter from having a covered atrium. It was decided that energy consumption figures would be evaluated after the performance of the building design had been optimised / agreed.

Phases 2 & 3: Design Refinement

The Phase 1 study was undertaken to predict general trends in the performance of the building under worst case scenario conditions in summer and winter and assessed the building in large zones without considering specific issues in detail. This study raised a number of issues:

- What advice can be given on the detailed design of shading devices and selection of glazing systems to ensure the avoidance of overheating risk?
- What design of a false ceiling would ensure good thermal contact between the air and the structural mass?
- What would be the impact of introducing cellular offices around the periphery of the building?

Shading and Glazing: Additional studies showed that brise soleil would be of benefit on the south facade and of limited benefit on the east but west facing rooms would require additional protection. Triple glazing was compared with 'low-e' double glazing for both summer and winter performance. The results indicated that while in winter both performed similarly, in summer, 'low-e' glazing could present a greater risk of overheating due to 're-reflection' of incident infrared radiation back into the space. Between pane blinds were recommended for local control.

Thermal Inertia : Simulation was also used to assess the impact of design changes to the fabric and interior finishes. In particular, the effect on thermal performance of adding a lowered ceiling below the concrete soffit was examined by dividing the office space vertically into three zones; one zone above and one below the ceiling finish, in an attempt to predict movement of air between one zone and the other for a ventilation system with a floor supply and extract above the ceiling.

Ventilation : The impact on natural ventilation of a more cellular arrangement for peripheral offices was examined. The effect of this on cross flow ventilation was found to depend on the extent of cellularisation and as this could not be predicted with certainty, it was decided to adopt a mixed mode system supplying 4ac/h to the office core all year round with openable windows for local fresh air supply as deemed necessary.

Final Design

The final exercise was the simulation of the building over a year to examine comfort and energy consumption in order to establish whether the final design was indeed a 'low energy building'. It was decided to address this only after the form and fabric issues had been optimised.

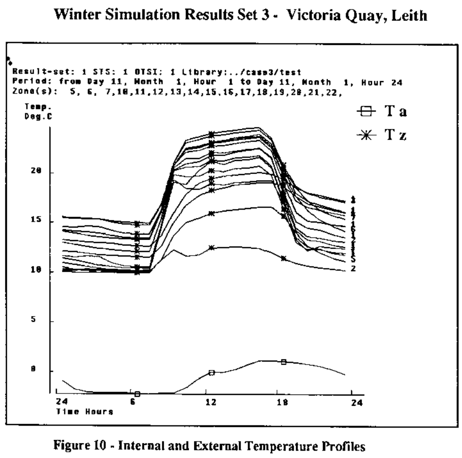
Details of the final design are as follows:

Winter: the building is mechanically ventilated, to reduce energy consumption. A perimeter heating system is provided, although results indicated that general casual gains from occupants, solar gain and electrical equipment could almost eliminate the need for this for most of the year. Feedback from the occupants, indicates that this is the case in practice.

Summer: the building uses a mix of natural and mechanical ventilation during the day. At night, the building is purged with night-time air, to pre-cool the structure.

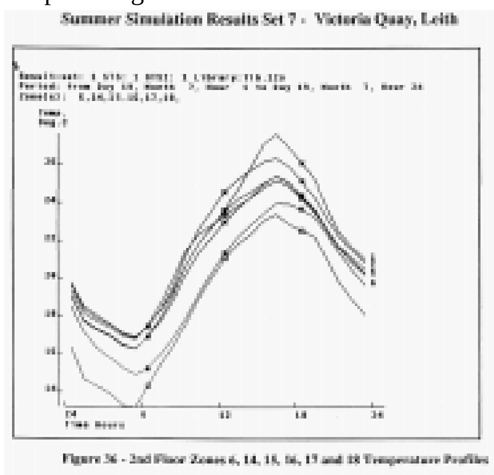
The initial studies established that a central atrium could achieve a significant energy saving over the winter period and should not affect the natural ventilation of the building during the summer. The building was predicted to perform satisfactorily as a non air-conditioned building, with no area exceeding 26^{o}C for more than 52 hours during occupied hours. The final solution incorporated most of the architects' original concepts and optimised thermal performance without compromising the practical requirements in terms of space planning. Features adopted included a heavyweight inner leaf to provide mass to external walls; triple glazing with blinds and shading devices on walls exposed to solar radiation. On site design changes which reduced the atrium-side openable fenestration may affect the effectiveness of the ventilation strategy. Feedback on this is not yet documented.

Graph 1 - fig 8



Winter temperature predictions

Graph 2 - fig 9



Summer temperature predictions

SIMULATION OPTIONS

There follows a list of design options not covered in this case for a variety of reasons. In some projects, further investigation of issues such as air movement and thermal studies in atria and qualitative and quantitative daylight analysis have been carried out on numerous projects. The outcome of these analyses are included in detail and in more general terms within the database case studies.

- CFD analysis of atrium - not carried out because the atria in this building are designed as circulation zones, sealed from the occupied area. It was not intended that these spaces should be heated or cooled, other than to provide frost and condensation protection via a high level heating pipe and the introduction of ventilation exhaust from elsewhere in the building. Had the design intent been to use atria as occupied space, further studies may have been undertaken.
- Daylight simulation - not done due to prediction that as a building which follows the accepted rules of thumb for natural light the building would be well daylit. However the final choices of interior finish for the office walls, the office furniture and partitions and the atrium and courtyard walls do affect daylight distribution but were not included in the original study.

FURTHER STUDY / POST OCCUPANCY EVALUATION

The building is being subjected to further analysis through inclusion in the in the aforementioned Applications Manual for Building Energy Modelling, where the simulation process is examined in more detail. In addition, the daylighting and artificial lighting systems are being evaluated and re-simulated under the Joule II Daylight Europe project, and a Post Occupancy Evaluation will be undertaken providing an opportunity to compare the actual with the theoretical.

This large office building was selected to illustrate how a design team can build up knowledge gradually over the design phase and the scope to examine methodologies for the application of simulation. Victoria Quay is also one of the most developed of the EDAS Database case studies and is used to demonstrate the potential to 'layer' design issues and simulation issues studied in the context of this live project. This does not mean that all aspects of the building were examined through simulation. In this case, analysis focused on the thermal performance of the building, because the designers had addressed other aspects such as daylighting through the treatment of the building form. EDAS assisted in the 'fine tuning' of the design based on best practice principles and exemplars in conjunction with the simulation exercise. The case study is intended to illustrate the fact that while 'design guidelines' can be applied in the early design stages, as no two buildings are the same, the ideal solution in one case cannot be applied 'ad hoc'. For example, design decisions and client requirements outwith the control of modelling teams and the designers, resulted in a building which evolved from the original concept. Even then, on-site decisions beyond the control of those involved at the design stage, also affect the final outcome. Just as design guidelines and experience are not always adequate, the application of a simulation modelling methodology through step by step instructions will not necessarily lead to the production of a building which fulfils all of the predictions. By analysing as many of our building projects as possible using the methods outlined, it is hoped that similar patterns and methodologies will emerge which will enable us to be better informed in our understanding of the design process, the translation of this to a simulation methodology and ultimately how this can influence the way buildings perform in practice.

EDAS - THE FUTURE

Investigations for the potential of a European-wide EDAS are already underway. However, current client feedback highlights the lack of 'red tape', quick response and independent nature of the scheme as some of its main assets, and it has been acknowledged that the addition of any level of bureaucracy could be detrimental to the schemes operation. It could also have an adverse effect on the smooth running and cost to set-up the service. Provided the regional centres liaise with each other and can arrange to be managed by a single organisation or group, administrative costs could be minimised and the centres could continue with the core activities of advice giving and design support activities.

Further afield, in response to the recognised success of the UK Scheme, there is growing interest in EDAS - type design advice in the Far East, with pilot schemes for Hong Kong, Shanghai and Malaysia under investigation.

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2. Best Practice Programme - Introduction to Energy Efficiency in Buildings Series - Published by the UK Department of the Environment - 1994.

3. 'An Application Manual for Building Energy and Environmental Modelling' - P. Strachan et al Proceedings - Building Simulation '97.

4. Information on Building Energy and Environmental Modelling Applications Manual available from the Chartered Institute of Building Services Engineers (CIBSE) - Delta House, 222 Balham Road, LONDON, UK.

5. Victoria Quay is now occupied and is undergoing a Post Occupancy Evaluation by the users and a detailed thermal and daylight study of the special daylight features and lighting control systems as part of the Commission of the European Communities Joule II Project - Daylight Europe.